by Joe Cooper, carm_popcomm@hotmail.com

Software-Defined Radio—Part I
Is It A Computer Or A Radio?

Back when I was a kid I had the opportunity to witness some interesting technological transformations taking place around me. For example, I watched the gradual disappearance of steam locomotives as they were replaced by diesel. Likewise, my family took me on trips on some of the last piston-driven commercial aircraft, which were being replaced by turbine-driven prop-planes and then jets.

For those who live through such periods there is always a great nostalgia for what was lost. Frankly I've got some great memories of my father keeping pace with steam locomotives as we drove along a road paralleling the track. And of our local airport, which used to be little more than a glorified bus station but is now a huge composite of multiple buildings, runways, and facilities. The same applies to radios, and to TV sets for that matter. My family was fortunate enough to be one of the first in our city to be able to own a TV, with which we could pick up all of two channels, both in black and white, of course. We also had some great old console radios from the 1940s with multiple bands for picking up shortwave broadcasters.

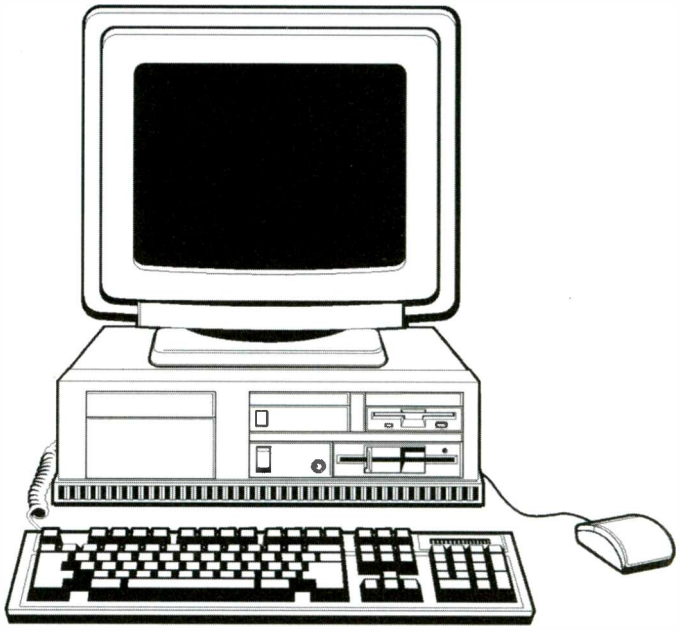
Like a lot of people of my generation my interest in radio and electronics came out of household radios and appliances. In that regard, there were two radios that got me hooked: a 1939 RCA "Globetrotter" multi-band shortwave radio and a 1960 "Spanmaster" two-tube regenerative shortwave kit. The originals were lost or given away many years ago, but I've been able to pick up working replacements at radio swap meets. I still get a lot of pleasure out of firing them up every once in a while and listening to some DX stations on the AM broadcast band or to those shortwave broadcasters still on the air today.

The New Digital Era

While nostalgia is an enjoyable personal pastime, today's reality is that we are now firmly in the grip of the digital age. AM and even FM are now the steam engines and prop-planes of this current generation. Frankly anything to do with analog electronics (that is anything that is dependent upon a continuously variable electronic signal rather than digital electronics' discrete non-continuous values) is on its way out. Given the tremendous number of benefits offered to us through digital technology, this new development holds great promise of better consumer products and radio equipment. That promise is better quality sound and pictures, more channels to choose from, greater range of programs, CD-quality sound from shortwave broadcasters, and exciting new digital modes for ham radio operators.

Yes, we are definitely moving into a brave new world of improved communication that is being brought about through the broad application of digital technology, and we will all benefit from the results.

Or will we? Let's just consider something that is very important about analog radio transmissions.



With either AM or FM transmissions (or even Morse code and radio teletype) you could always receive the signal, even if the intelligence (that is the message) was being jammed. Think about all those heroic moments during the 1930s, or World War II, or during the Cold War when "the Free Nations" broadcast news and information to people in fascist and communist countries. The only way that information could be blocked was through direct jamming of the broadcast signals. But if someone was careful enough and quick enough, he or she could find a clear signal and be able to hear information from an alternative point of view. Let's not forget that listening to that information was illegal, and to be caught was to risk torture, imprisonment, and even death.

The point is that during that period a person with a suitable length of copper wire, a rusty razor blade, a lead pencil, and a metal safety pin could build a serviceable radio that was undetectable. What I'm talking about here is, of course, a variation on a crystal radio, substituting the razor blade for the crystal detector. The fact is that analog technology is simple technology, which you can literally create out of household items. I've seen crystal radios made out of tin foil, bathroom tissue tubes, kitchen knives, and the headphones made using either tuna or cat food tins. In fact, back during WWII, many people would build crystal radios into wooden doors, with a secret built-in hiding spot for the headset and tuning apparatus. The antenna would be wound around the edge of the door, so it would act like a loop, and thus not only have a degree of amplification, but be directional as well. Because it was not a super-heterodyne design, a crystal radio did not have an oscillator circuit. Both the Germans and the Russians had trucks out in the streets

Here's an example of a WWII vintage U.S. Navy receiver that represents the analog way of doing things. It was big, heavy, and powerful, but it received only one frequency at a time. It worked in its day, but only with a lot of human intervention and interpretation.

listening for the oscillator circuits of illegal radio receiving sets, but the crystal radio was completely invisible to them.

But try to build a radio that will allow you to either employ today's digital technology or listen to new digital modes by using simple household items. It is simply not possible.

The Implications Of Digital Technology

In this month's column I want to introduce you to some very big developments that are taking place right now in the field of radio design; developments that are going to radically change the way radios are both made and used. Much of today's radio (and television) technology is not that far evolved from the time that Heinrich Hertz demonstrated the existence of radio waves, around 1885. Most modes of radio transmission and reception still use his basic model, which is to broadcast radio waves from a transmitter and have the receiver passively pick up the signal using an antenna. But the old Hertzian model of broadcast radio is going to be scrapped and replaced with an entirely new paradigm of radio use. This change is going to be very significant. It's happening right now and it's going to directly affect the way you and everyone else will be using radio technology throughout the 21st Century.

Let me introduce this new paradigm of radio use to you using the old *StarTrek* series as a model. Just about everyone is familiar with the classical TV show that originally aired in the late 1960s. There were two iconic images presented on that show that stick in people's mind: that of the handheld communicator used when Captain Kirk and his crew would go off-ship to explore a new world, and that of Lt. Uhura sitting at her communications console keeping in touch with him and relaying messages to other members of the crew on the bridge.

It's pretty easy to see that what Captain Kirk had in his hand was a souped-up version of today's cell phone, and not surprisingly, many of today's cell phones look a lot like the *StarTrek* version. Some would argue that today's cell phones are even better because they have built in cameras and text messaging, while all Kirk could do was wiggle a few knobs and dials when he had trouble hearing the ship. More importantly, as you'll remember if you were a hard-core fan, when Kirk was onboard the *Enterprise* he had to walk over to what were basically intercoms scattered around the ship. The communicator was used from time to time, but generally only in a time of real emergency, and then it still had to be routed through Lt. Uhura's console. Speaking of Lt. Uhura's, console, today you'll find her communications console in a host of settings, including military, police, fire, and other public safety services (though I don't know how many of them are being manned by women in short skirt uniforms and tall boots as was then envisioned as our future).

I think we can all see how the original *StarTrek* communications system works today using fairly conventional technology. Yet, ironically enough, *StarTrek*'s model of radio communications in the 22nd Century is precisely the *old* paradigm that we are going to be saying goodbye to in the very near future. Now let's consider the type of radio system used in a subsequent series, such as *StarTrek: The Next Generation*. There the bulky handheld communicator was gone and people instead wore a new technology called a "Comm Badge." You've seen on the re-runs where Captain Picard is in conversation with one of his crewmen, when out of the blue someone calls him, apparently out of the thin air. Rather than looking startled and surprised, Picard sharply taps the badge on his chest and says "Picard here," and begins conversing with someone else over a comm-link. Just to be able to communicate like that would be very impressive, given that the Comm Badge is about as big as a silver dollar. But, wait, there's more!

Captain Picard, and everyone else aboard his ship, is able to use these Comm Badges everywhere—in a Jeffries tube, in an elevator, on a shuttle, down on a planet's surface. Just try doing that with your cell phone and see how long it will be before you get an "out of service area" message. Likewise, the Comm Badge is also directly linked to the ship's computer and can perform a wide range of tasks other than voice communication. If Picard wants to know exactly where a crewman is, all he has to do is ask the computer and an answer is instantly forthcoming. On top of all that, the Comm Badge can also provide a wide range of medical information about the person wearing it, along with environmental information about where they are, to name only a few important functions. More importantly, the communications console no longer exists as a separate function on Picard's version of the *Enterprise*. It's now been delegated off to either Lt. Commander Data or Warf, depending upon the urgency of the situation, and they do communications tasks along with a host of duties.

One big technology change that took place between the original *StarTrek* series *and The Next Generation* was that any console could become the communications console. That was because the console was actually a computer screen with a touch-sensitive surface, so its function could be re-programmed instantaneously. Lt. Uhura's post was definitely an analog device with all sorts of mechanical buttons, always threatening to break her rather long fingernails. It was definitely hard wired because if anything went wrong large sparks would spray from its innards, which would have to be accessed by opening a panel in the bottom, exposing the very visible wires.

So, when all is said and done, what was "futuristic" in 1968 when the original *StarTrek* first aired is pretty much standard today, and in some ways even superseded by our current technology. Yet what if I said that much of the apparently more advanced technology featured in *The Next Generation* is about

The AN/USC-61 Digital Modular Radio (DMR). The new radio communications standard for the U.S. Navy for the 21st Century. Able to transmit on any frequency between 2 and 2000 MHz, this unit is no bigger than a mini-fridge and can be programmed into any configuration needed "in the field" using the appropriate software program. (Photo courtesy Joint Tactical Radio System Program Office)

to become available to us now? That's the important paradigm change we're now facing thanks to a true merger of radios and computers, and it's going to radically change the way both those technologies are fashioned and used.

Is It A Computer Or A Radio?

Two new terms you're going to hear a lot in the upcoming years are software radio and cognitive radio. Over the next series of columns I'll be explaining to you what they are and how they'll impact both the computer and radio industries.

Software and cognitive radio are already transforming the way in which communication functions are performed around the world. At this time the primary driving force behind this transformation is, not surprisingly, the United States Navy, followed by the Joint Tactical Radio System initiative (JTRS). Already the US Navy has in operation a new system of communications called Digital Modular Radio (DMR). Rather than having a room full of radios as before, the DMR is a fully computerized system that fits into a small box about the size of a mini-bar fridge. How exactly do you get a whole room full of radio equipment down to something that small? The answer is simple: you eliminate all your bulky hardware by turning it into virtual components in a computer program.

Remember the series I did on the Ten-Tec RX-320 in which I introduced you to the concept of virtual radio components? At that time I showed you how the theory of virtual components originated just before World War II and finally came to be developed using mainframe computers during the 1970s. Everyone at that time thought they would never come into practical use because of the amount of computational power that was needed. But thanks to the development of the PC computer, and a whole new generation of high-power CPUs to go with them, that technology came to be available.

In that series I demonstrated how programmable devices can be used to create some virtual components within a radio system. You may also remember that the RX-320 was made up of two circuit boards: the RF tuning section and the DSP processing section. The DSP section was itself made up of three chips: the mini-computer where the DSP circuitry was created in virtual form, the ROM chip that held the programming to create the virtual components, and a modem chip to allow you to hook up the radio to your computer via a serial cable. Now, with true software-defined radio even that RF circuit board is eliminated. In a true virtual radio, what happens instead is that broad chunks of the RF spectrum are sampled, turned into digital information, and then processed.

This ability to sample large sections of radio spectrum opens up some very significant monitoring and signal processing possibilities. I've already told you about the SDR-14, manufactured by a company called RFSpace, that samples all radio events between 0 and 30 MHz. With your conventional radio you can pick out one signal among many that are picked up by your antenna, then amplify and detect it. With a software-defined radio, you capture every single signal on that antenna, convert them all into digital form, then use DSP to pick out the one you want to monitor.

To give you an idea of just one possibility available to you with the SDR-14, you can digitally record all of the radio activity that takes place on any 150-kHz wide segment of the RF spectrum from 0 to 30 MHz on your computer for up to 24 hours. You can then go back and check any and all activity in that 150-kHz spectrum found within that recording. Let's say, for instance, you're listening to a segment of the 40-meter ham band; you can listen to every single Morse code (CW),

This is a field version of one of the new generations of cognitive radios being used by the U.S. military. What is eliminated is the old "he who pushes the button first with the loudest signal gets heard." With this radio nobody goes unheard. (Photo courtesy Chaotic.com)

voice, or broadcast signal that took place during that time, no matter when it occurred. You can have three broadcasts going on at the same time and each would be recorded, then you can go back and listen to each one at your leisure.

Again, what makes software-defined radio special is that it samples a very large chunk of RF spectrum and then uses software-defined circuitry to process all that information. As you can see, with a highly sophisticated software program you could route and control a vast number of communications streams using a number of different modes.

What is most significant about software radio is how it will end the Hertzian Paradigm that traditional radio transmission and reception is built upon. What do I mean by that? Well, simply listen at night to an AM broadcast radio on a channel that does not have a strong local station. What you will often hear is hodgepodge of stations, with the strongest station standing out from the others. That has always been the problem with "classic" radio—you needed either more power or fewer stations on a channel in order to be heard clearly. That's why such things as "clear channels" were developed in AM radio, as well as non-interfering antenna broadcast patterns for TV and FM radio.

The problem with that solution, though, is that it requires a lot of very expensive RF real estate and equally expensive transmitters and antennas. However, once you get into more chaotic situations, like a military battle, you run into even more difficulty trying to keep on-the-air discipline. The truth is that if you have one channel and multiple operators, it's going to sound like bedlam when everyone presses the transmit key at the same time. Once that happens, it's just as if you have no communications ability at all.

So the real promise of software and cognitive radio is no more pile ups or missed messages. Just a smooth, seamless integration of messages that all get to the proper place at the proper time and in the intended format, whether voice, video, text, or data. More importantly, all of these messages are 100 percent encrypted, private, and secure, so the information contained is only used by the people for whom it was intended. Imagine the possibilities.

Radios That "Think"

The U.S. Navy is not committed to the development of software radios simply because of the significant reduction in the size of the components (though it's certainly a welcome feature on submarines, where they are now extensively used). What is more critical to the Navy is that there is also a significant reduction in size for those communication units used by Naval personnel. What is being talked about, frankly, is wearable communications gear, as in the *StarTrek* comm badge.

However, I'm not talking about a new type of walkie-talkie here, but an entirely new way to keep people connected through an entirely new paradigm of communication, using an active interaction between a radio and its operating environment. This is called "cognitive radio," which is based upon software-defined radio. These are radios that are "aware" of their surroundings, so to speak, and which re-define themselves in order to work properly as those environments change.

Let's take a conventional example, a Family Radio Service (FRS) radio. I'll use it to illustrate the current limitation of the Hertzian Paradigm and how a software-defined cognitive radio will create a new paradigm. Say two people are each using an FRS radio out in an open space and they are walking away from each other. As they do so, the signals start to fade to the point where communication is broken. In order to hear each other, they have to walk back toward each other. The point here is that radio waves lose power at the rate of the square of the original power once they leave an antenna. The only way you can fix this is to either increase the power being used or improve the antenna. Why? Because if you look at the original system that Hertz invented, it was made up of only an antenna and a source of RF power. Nothing much has changed since then. Really, all a conventional radio does is help the antenna along by tuning and amplifying the signal.

Cognitive radio, on the other hand, looks at the entire radio spectrum and "decides" what part of that spectrum it will use. Let me replace those FRS radios those two people were using with brand new software-defined radios with cognitive abilities. First off, these new radio units are only a fraction of the size of the original FRS radios and have no controls other than on and off. Our two people are in different parts of a house and one of them wants to go out for a walk. Using the same wireless computer network that these people connect up to with their laptop computers, they are able to talk to each other using these radios over that network. It's low power, encrypted, and each of the radios "knows" to connect up to the network and how to find the other radio by voice commands. The two people now go out for a walk, and if they want to talk to each other they can, this time by using a low-power cellular network found throughout the neighborhood. There is no fading or dead spots in this system, so each time they communicate the signal is 100 percent clear.

Now say one of the people steps into a store; the radios note that this has happened. The radio in the store then connects up to the wireless network in that building and routes the signal back to the

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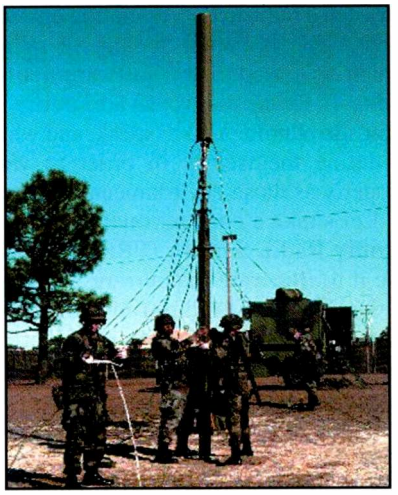
friend standing outside the store using a link between the store's system and the low-power cellular network. After having picked up some picnic supplies, our two friends head out to the country using public transportation. Again, if they are split up, even if they are riding on a bus or in a subway, they will still be in contact with each other as the entire system contains a low-power communications network that enables people to remain in touch. In fact, while traveling outside of the city, our two friends are also able to talk with other people in other cities and other parts of the world if they want to. The Internet can route their messages to other systems and can find anyone who has his or her communicator on. Finally our friends get to their destination and head out into the country via a trail. Here they may keep in contact via a conventional cell system, much like today's cell phones, or their communicators may switch over to a low-power communications satellite circling the Earth in low orbit. Throughout their journey, our friends have stayed in touch because their communications devices switch back and forth between various systems, always ensuring contact.

This is *not* science fiction, but working technology that is available off the shelf today. I've worked hands-on with earlier versions of cognitive radio back in the late 1990s when you still required a 20-pound box of radio and computer parts to make it work. However, the significant change is software-defined radio itself, which has reduced to a fraction the size of the equipment.

What has also changed significantly is the way in which software-defined radio eliminates the communications barrier caused by multiple standards. Consider for a moment that cell phones have standards such as GPRS, EDGE, and UMTS that prevent phones from sharing information with others. The fact of the matter is that without technological convergence to one standard, current cell phone technology is rapidly reaching a dead end. Also, if they remain on a circuit-based technology, cell phones will need to become bigger, run hotter, and require larger batteries. By switching to software-defined radios, all of these problems are eliminated. More than that, a software-defined radio with cognitive ability would also be able to include data processing, entertainment functions (including high-definition TV), global positioning functions, group-based video games, and maybe some tricks that are just now being thought up by some 16-year-old genius.



Today's US military's tactic is not just to gain control of the ground, sea, and air during a conflict, but the radio spectrum as well. Software-defined radio systems with cognitive capability will instantly adapt to the frequency allocations of a country or region and be able to sort out the signals of the good guys from the bad very quickly. (Photo courtesy Armed Forces Communications and Electronics Association)

You can see why the U.S. Navy and other military services are excited about all this. Imagine being able to send your troops out into the field supplied with wrist-based communications units. They would be able to access real-time data, such as maps and video feeds of an area, and be able to see the location of each of their teammates superimposed on that map. The communications device would only be wearable by that person because it would be linked to a chip implanted on his or her body, so it could not fall into enemy hands—and the digital signal being supplied would be completely encrypted and secure.

Again, none of what I am writing about is science fiction; it's all there ready to be used and the early versions are already out in the field!

Big Brother Lurks In The FCC

Now, having told you all about this wonderful new technology, there are a few things you need to know regarding how the FCC may keep *you* from using it. Right now we're at the same point in the radio-monitoring hobby as we were back in 1919 when the U.S. Navy was set to see all amateur activity banned, including the private ownership of radio receivers. Let's not forget that it was only through the lobbying efforts of people like Hiram Percy Maxim, one of the founders of the American Radio Relay League, that this prohibition was prevented and we were "allowed" to monitor a significant portion of the radio frequencies.

Today, however, it is not the radio monitoring hobbyists who are working to keep the radio waves open to radio monitoring. The fact is, it is the computer hobbyists who have taken up the cause and grabbed hold of the concepts of software-defined and cognitive radio. They're the ones working hard to keep this new digital technology accessible to the ordinary person and out of the control of corporate and government interests. They are the ones—not the radio monitoring community—who are really grappling with the issues over who really owns this technology and who will ultimately control it. What the computer and personal rights activists have confronted, and which the radio monitoring community has not, is that there are laws already in place to control this new radio technology and who will use it. More importantly, these laws are *not* designed to protect your rights, but are there simply for the benefit of corporate interests.

At this time the key issue is the "broadcast flag," and it's being focused on the new high-definition television (HDTV) technology that's currently gaining ground. A broadcast flag is a copy protection method for HD digital TV programming. The HD digital television's circuitry contains a tamperproof device that will detect a "flag" embedded into the broadcaster's signal. Once detected by the television's circuits, the flag will prevent the program contained in the signal from being copied in full HD digital quality. The HD television will only allow an inferior quality copy of a program's image, and even then you will only be able to copy using an FCC-authorized device that can also detect that broadcast flag. In fact, the broadcast flag can also be used to prevent any copying at all if the broadcaster wants that option because of copyrights.

What is of great importance here is that it will be illegal for hobbyists or experimenters to build or use devices that can circumvent a digital flag, even if it's just to make HD copies for their personal use. In this regard the FCC is specifically targeting hackers and the manufacturers of devices designed to foil a broadcast flag. The penalties for such activity will be prohibitively high and the FCC promises strict enforcement in order to protect the interests of copyright holders in the entertainment business.

As of July 1 of this year, all HDTVs manufactured in the United States will

have to be digital-flag compliant, *even if you build it yourself.* Right now, throughout the United States there are people who are sharing plans and technology to convert their computers into a HDTVs in order to beat the deadline so they can own a legal device with which to make off-the-air copies of TV programs.

Now here is the point:

It is perfectly legal to make off-the-air copies of TV programs, or to record what you hear on your radio for that matter, and it will remain so after July 1. Likewise Congress has not made any law regarding the digital flag—it is a regulation solely set by the FCC. More importantly, the origin for this regulation came directly from Hollywood, not from any lawmaker. An organization called the "Broadcast Protection Discussion Group," which was little more than a high-priced lobby group for American Broadcasters and Film Studios, swept aside any protest and had "their" regulations put into place. The bottom line is that a broadcaster will be able to insert a broadcast flag into its digital stream and that flag will program your HDTV, or any "legal" copy device hooked up to it, to prevent it from copying.

Now if you think you're simply going to hack together a work-around device or modify an existing one, forget it. First off, an important part of the FCC regulations puts a strong onus upon equipment manufacturers to make their goods completely tamper-proof. Second, the penalties will be steep enough to deter you from being an ardent defender of civil rights unless you've got very deep pockets.

What seems to have been forgotten in all this is that the electromagnetic spectrum, broadcast frequencies, and even the copyright laws themselves are held in the public trust by the FCC and the federal government. Your interests, not those of corporations, *should* be the first concern of any federal or state agency if the United States government is truly "of and by" the people.

The Implication Of Broadcast Flags For Radio Monitoring

So why should broadcast flags be an issue for people whose hobby is monitoring radio signals with general coverage receivers or scanners? What would be the impact on the radio-monitoring hobby of not being able to copy a TV show off the air in its original HD format? That's what we'll look at next month as we delve deeper into how software-defined radio actually works. Frankly, all the columns I've written since the beginning of 2002 have led to this technological convergence point, where we begin to move into an entirely new paradigm of radio construction and operation. If you have back copies of *Pop'Comm* on hand, do yourself a favor and review them, particularly the issues on computer sound cards, audio sampling techniques, and using virtual components. The information I provided there will be critical for understanding how software-defined radios sample broad sections of RF spectrum and then process them into usable information, no matter what format they were originally in.

As I said at that beginning of the column, I've seen a lot of change in my time. From that experience I have a lot of sentimental feelings about many things that have changed or simply no longer exist. The truth, though, is that if you want to grow, you have to learn to let go. I'm afraid that as software-defined radio and cognitive radio become more established, many features of the old analog radio world that we enjoyed so much will disappear. Again, with all gain, some loss occurs, and I'm sure each of us has his own example that to draw upon. The bottom line is that with digital technology it's very easy for the government to require that certain features be included in the design of a software-defined radio that would make it impossible to monitor certain frequencies or modes of transmissions. Those same laws could be used to prevent the sale of the technology, such as high-speed RF sampling devices, needed to create software-defined radios.

The precedence has already been set with the restrictions being placed upon HDTV technology as of July 1, and there is absolutely nothing saying that the same restrictions could not be placed upon monitoring radios. There is already precedence there with the blocking of 800-MHz cell phone frequencies, and there is more legislation where that one came from. Right now it's the computer geeks and civil rights activists who are carrying the ball for us radio monitoring types regarding our future freedom to be able to listen to what we want. They're hiring the lawyers and fighting the FCC in court to enable us to build our own software-defined HDTV sets in the future. It's not a big jump to see that the precedents set in those court cases will determine whether we will be able to monitor a wide range of radio frequencies with "conventional" or homebrew software-defined radios, let alone record what we hear even if we can tune them across the radio spectrum.

So are we going to let the geeks and the activists work alone, or are we going to help them? The answer to that question will determine if there will still be a radio monitoring hobby over the next 10 to 20 years. The choice is entirely yours. Don't let the FCC make it for you simply because nobody was there to speak up for your interests. Remember, radio monitoring has never been a right that was Constitutionally guaranteed, but a gentleman's agreement laid out in the laws governing the use of radio as it existed under the old Hertzian Paradigm of radio transmission and reception. Once that paradigm ends and is replaced by a new one representing software-defined radio, does that old agreement end?

It's as simple as that. We have to create an entirely new agreement from scratch. Are you ready?

Drop Me A Line

You can e-mail me with any questions at carm_popcomm @hotmail.com. As mentioned before, I cannot answer general questions on computers, but will be more than happy to help you with any issues raised in the columns. You can also write to me at "Computer-Assisted Radio Monitoring," Popular Communications, 25 Newbridge Road, Hicksville, NY 11801.

I have placed a list of the columns I've done over the past two years, along with a summary of the content, on my webpage, which has moved to www3.sympatico.ca/joe_in_ey. There you'll also find instructions on how to purchase back issues of *Popular Communications*. Remember that I cannot release previously published material as *Pop'Comm* owns the copyright. Also, please remember that I'm interested in any pictures you may have of your own computer-assisted monitoring station or stories about how you have built and run it.

Lastly, remember our troops overseas and give them your support. The "Any Service Person" mail program has been suspended for security reasons, but you can refer to the U.S. Department of Defense's official webpage, "Defend America." They have a specific section found at http://www.defendamerica.mil/support_troops.html, which has an amazingly wide range of practical and useful ways you can directly help. Please take some time to check out the resources suggested on that webpage and put them to use. ■

by Joe Cooper, carm_popcomm@hotmail.com

Software-defined Radio—Part II
Getting Used To It In Its Early Stages!

Last month I introduced you to a significant trend that is going to have a big impact on radio communication in the immediate future. That new trend is being spearheaded by the development of two new technologies called "Software Defined Radio" (or SD Radio) and "Cognitive Radio" (or Cog Radio). This month I'm going to outline the theory and practice behind the construction of a SD Radio so you can better understand how this technology differs so radically from how radios have been designed and constructed in the past. This will lead into the next column, where I will outline how you can actually *build* your own SD Radio using a home computer running the LINX operating system and some special (but not hard to get) hardware components.

If you have been following this column since its beginnings three years ago you have all the technical background required to understand the theory and practice of SD Radio. This is where all the ideas I've discussed come together and become extremely relevant to the "new school" of radio monitoring that I've been talking about. I'm not talking about a "fad" here, but a complete paradigm shift in technology that's being driven by a $25 billion investment by the United States military through the JTRS (Joint Tactical Radio System) initiative. The goal is to have one platform that will support 33 waveform profiles, including cellular phone standards, over a frequency range of 2 MHz to 55 GHz. There is also a massive international involvement in the development of this technology for JTRS on the part of companies such as Boeing, Singular Wireless, General Dynamics, Intel, Lockheed Martin, Northrop Grumman, and Raytheon, just to name a handful of those involved (and I've not even touched on universities, research groups, government agencies like NASA, and so forth).

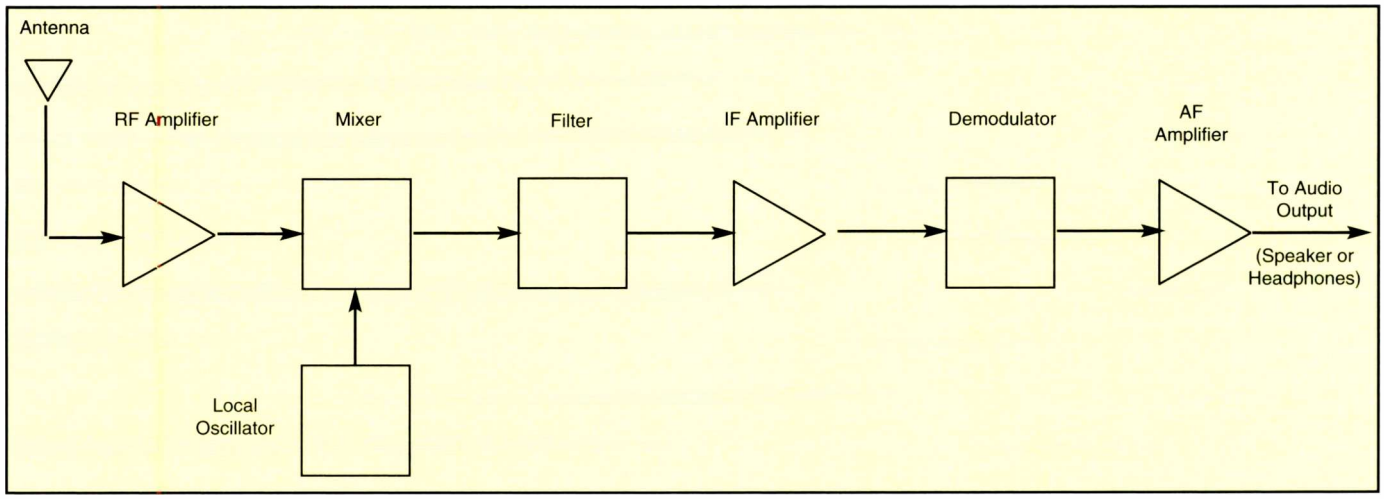
A Shrinking, But Powerful, Technology

The goal of all of this work and research is to eliminate the need to have a truck filled with multiple radios and operators, along with a patch system for cross-mode or agency communications, and to replace it with one small box about the size of a mini-fridge. More importantly, once you have this small box in place, all you have to do is plug your computerized device into it and it connects up automatically. Once that happens you will be talking to the person you need to without interference and in a mode that will give you the proper amount of information (voice, text, graphics or whatever). This device can do all this because, other than the "container" (which is really nothing more than a specialized computer), all its radio components and circuits are "virtual." By that I mean that rather than being the "real" physical components that used to take up large amounts of space and power, they are now represented as mathematical equations in computer software.

By using special analog-to-digital converters to turn the radio signals into "real-time" digital form, these software based radio circuits are able to process these digitized radio signals in exactly the same way as coils, capacitors, and transistors used to. What's even more exciting about this new technology, particularly for increasingly cost-conscious military and government purchasers, is the impact that SD Radio will have upon the economics involved in upgrading to new technology. By agreeing on a standard for the main "box" that will run the software, so that its design will remain fairly constant and unchanging over the next few years, all necessary design changes can focus on the software being used. Significant generational changes in circuit design will be accomplished by simply uploading the new software into the box, which can be used for several generations before the box itself will need a re-design.

The bottom line for radio monitoring is that if we want to continue to be active participants in our own hobby we are going to have to learn some significant new skills. We're going to be building radios using computer programming rather than with soldering irons and some components we bought down at the electronic supply store. If we don't develop these skills within our ranks, we are going to end up being appliance operators who will be at the mercy of the equipment manufacturer to supply us with our products (as if we are not almost at that point already).

What's worse, this new digital technology contains something that the old analog equipment didn't—the ability to contain built-in, tamper-proof controls that will prevent you from listening to, or recording, a wide range of signals. There is already a precedence set: a new FCC regulation that specifically prohibits ordinary citizens from building their own SD Radios



This block diagram illustrates the basic parts of a typical Super Heterodyne radio. It works by mixing an amplified radio frequency (RF) signal that has been tuned from the radio's antenna with another RF signal produced by the local oscillator. Through a process called heterodyning, these two signals are mixed together to produce a third intermediate frequency (IF) signal. This IF signal remains fixed on one constant frequency, which is much easier to filter and amplify than all the multiple frequencies available to you when you tune directly from the antenna. Originally invented by Edwin Howard Armstrong in 1918, the Super Heterodyne has been so successful that it became the foundation for virtually all radios designed and built from the early 1920s through today.

with high-definition television (HDTV) reception capability will come into effect on July 1, 2005. As I pointed out in last month's column, the reason for this is to prevent people from making high-quality copies of HDTV programs. This is important because, in the end, an SD Radio that can monitor HF, VHF, or UHF radio frequencies can also be used to receive and decode HDTV signals. This is not a case of comparing apples and oranges because it's all about a "one box does all" type of technology where the entire spectrum of radio frequencies go in one end and you get to choose whatever medium you want to use coming out the other. Your ability to have unrestricted access to this new technology is now being fought for by activists in the computer and civil rights fields, such as the Electronic Frontiers Foundation (http://www.eff.org) and the Free Software (as in free speech) Foundation (http://www.fsf.org). I will tell you more about these organization, and others, in a separate column.

So now that you have a good idea about the background issues surrounding SD Radio, let's take a look at the theory behind its construction and operation. As you'll see, SD Radio is a radical departure from the types of receiving equipment you're used to using, including those that employ PLL (phase lock loop) tuning or DSP (digital signal processing); this is a whole new way of doing things. Like it or not, it is the way in which we are going to be building and using radio technology for the next few decades, or until something equally new comes along to replace it. So whatever you may think about SD Radio, this what radio will be in the 21st Century. Better get used to it by learning more about it now while it's still in the early planning and deployment stage.

SD Radio Basics

What exactly is the difference between an SD Radio and a conventional radio? Frankly, at this time giving a *specific* answer is difficult because the term SD Radio refers to a variety of technologies that are slowly emerging into a final form.

The goal of the engineers developing an "ultimate" SD Radio is to create a device composed of a single non-changeable hardware platform through which upgradable computer software is run that is used to define the mode(s) of transmission and reception which will be available when the radio is in operation. Part of that goal is to develop an ultimate "black box" SD Radio that would be capable of receiving and transmitting in any mode, on any frequencies in the RF spectrum at any time, and with multiple operators. Such a radio would never require its hardware to be upgraded, because all the hardware functions would be dedicated to simple operations, such as running the processing software or amplifying sent or received signals. More importantly, the actual configuration of that SD Radio circuitry could be constantly changed or modified "on the fly," because it would be made up of "virtual" components defined through computer software that was easily uploaded into the aforementioned hardware. The ultimate aim of this device would be to overcome the problems faced by conventional radio systems where differences in hardware platforms and the modes of communication employed prevent one or more people from being able to communicate with each other.

In practical terms a person can now own a cell phone, cordless phone, wireless Internet gadget, pager, GPS tracker, wireless intercoms, ham radios, Citizens Band radios, FRS radios, and more. Each one of these can use their own special circuitry, band of frequencies, and mode of transmission, all of which requires a great deal of regulation, government inspection and monitoring, plus specialized production. By switching to an SD Radio, however, the hardware would be reduced to a single generic base that is configurable for specific tasks by the use of modules (such as antennas or RF front ends). That hardware would then run computer software, which would allow multiple protocols of communications, and even complete reconfigurations of a radio's features and functions via a simple download, rather than having to purchase an entirely new radio. By taking this approach the entire question of "how do I connect to someone or some service over a radio?" is replaced by "which service or person do I want to connect to over a radio?" With

SD Radio that connection is completely transparent, to the point of being automatic, for the user because all the steps and procedures required to do so are managed by software.

So again, how is this different from today's radio systems? Let's take a look at what makes today's "conventional radios" what they are.

The Problem With Conventional Radios

All radio transmissions going back to the days of Marconi's early experiments are based upon the modification of the amplitude or frequency of a radio frequency (RF) carrier of some type. In order to transmit a radio signal, some type of modulation must take place within the transmitter. More importantly, since all RF transmissions exist in a range of electromagnetic frequencies that are beyond capabilities of the human senses, they must be converted back into a form that a person can either see or hear. This is done through de-modulation circuitry in the radio, which removes the "intelligence" (words, music, text, data, or any other information) from the RF transmission and makes it available through a speaker, TV screen, or computer monitor (to list a few possible devices).

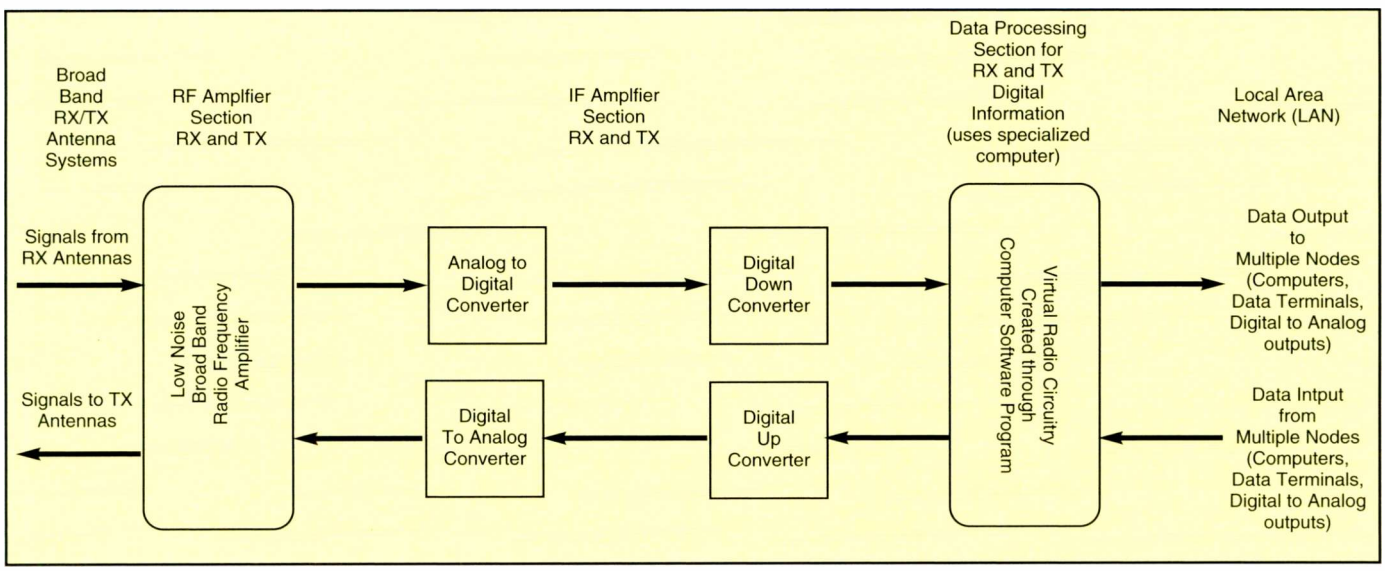
By definition then, all of today's conventional radios have one thing in common: all use fixed hardware circuits to convert an RF signal into either voice or data. So when you go into a store to buy a radio, each one has one or more built-in hardware circuits designed to demodulate specific intelligence according to your particular requirements. Now when you're talking about a conventional radio used for very general purposes, like an AM, FM, or shortwave radio, the issues involved in building and designing a demodulation circuit are not that complicated. Radios of this type have existed for years, with separate demodulator circuits built in and made accessible by simply using a switch or a button. However, when you get into more sophisticated modes of communication, particularly when it comes to commercial communications systems such as those used by emergency and public safety services, cell phone companies, and data communications, you start to run into some real problems. Communications of this type are increasingly taking place using shared frequencies, encryption techniques, digital IDs, and computerized switching, much of which is proprietary to a specific manufacturer.

At one time you'd deal with this problem of multiple modes and protocols by sticking with one manufacturer's brand and specify that if people wanted to talk to each other they would have to use that brand over another. That was all fine and good when people didn't move around that much or only had to deal with the employees of one service or company. The problem today is that we can't afford to keep everyone isolated from each other if we are going to be dealing with the big problems the world is facing. This hit home on 9/11, when it became obvious that because of too many different communications protocols in New York City and the surrounding metropolitan areas, the police, fire, ambulance, and other safety services simply could not talk to one another on that fateful day.

Even in day-to-day situations, it is absolutely critical that all of these groups remain in communication in order to deal with ordinary activities such as crime control. As it stands right now you can have a criminal being pursued from one jurisdiction to another in an automobile, for example, and in many instances there's absolutely no means of handing over the chase to another police force because of communication barriers between two systems.

Likewise, it's also clear that we are now living in a global economy with a global marketplace that's being held together through a wide variety of communications protocols, with cell phones playing a critical role. The fact that a cell phone from one company cannot transfer text data to another because of protocol incompatibilities, or simply will not work in another city or country, is a matter of real difficulty for the businessperson who may travel between three or four different countries *in one day*.

Again, having to use multiple radios to deal with multiple modes is not a solution, because it is not cost efficient, energy


Broad Band RX/TX Antenna Systems
RF Amplfier Section RX and TX
IF Amplfier Section RX and TX
Data Processing Section for RX and TX Digital Information (uses specialized computer)
Local Area Network (LAN)
Signals from RX Antennas
Signals to TX Antennas
Low Noise Broad Band Radio Frequency Amplifier
Analog to Digital Converter
Digital To Analog Converter
Digital Down Converter
Digital Up Converter
Virtual Radio Circuitry Created through Computer Software Program
Data Output to Multiple Nodes (Computers, Data Terminals, Digital to Analog outputs)
Data Intput from Multiple Nodes (Computers, Data Terminals, Digital to Analog outputs)

This block diagram shows the main components of a Software Defined (SD) Radio receiver (note that it is also capable of transmitting). Unlike the Super Heterodyne radio, the SD Radio does not receive on one single frequency. Instead it "samples" a broad band of radio frequencies all at once (which can range from several megahertz to many gigahertz) and then converts them into digital form for further processing. Software in the digital processor (or computer) "defines" how the radio is used by creating virtual radio circuits through which the digitized signals pass.

efficient, or user friendly. This is where SD Radio comes in.

Enter The SD Radio

Most of us who have worked with conventional radios are familiar with the basic layout of the circuitry. The majority of radios built today are a variation on the original design invented by Edwin Armstrong in 1918, called the Super Heterodyne receiver. The principle behind this type of receiver, sometimes called the Superhet, is that all frequencies being received are converted to single frequency, called an intermediate frequency (IF), which is then amplified using special IF amplifiers before being detected. The design has been extremely successful because of its overall simplicity and efficiency. Rather than having to amplify all the RF signals being received, which is a very difficult process in conventional analog circuits, only one narrow range of frequencies has to be boosted in strength. This method of amplification lends itself to easy approaches to filtering a signal and de-modulation.

However, while this all works very well when you are dealing with analog signals, it is very inefficient when applied to more sophisticated protocols, particularly those that employ high-speed digital signals. While you can replace some of the analog circuits with digital ones, such as when you use DSP to filter or amplify signals using simple virtual circuitry, it is not the same as true SD Radio.

What makes an SD Radio different from any other radio you may have used before, including those with DSP circuitry? The answer is in the amount of bandwidth that can be processed at any one time and the way in which it is processed. For instance, rather than taking one frequency off an antenna and converting it to a single frequency (as is done in a Superhet radio) and then amplifying and detecting it, the SD Radio amplifies *all* the frequencies from an antenna over a very wide bandwidth and then converts *all signals found in those frequencies—whether they're manmade or natural*—from analog into digital form. So to use the proper term, an SD Radio *samples* a broad bandwidth of the RF spectrum as it is received at the antenna, then amplifies it and digitizes it. Then, rather than detecting the intelligence in one signal, SD Radio uses its built-in software program to *process the information* contained in the digitized RF spectrum to gather the information found there, rather than using conventional detection circuits to do so. The intelligence found on the RF signal can then be passed on to any number of digital devices where it can be either displayed or converted into analog modes, such as audio sound.

Two factors are of special importance here: the broad bandwidth of the RF signal being sampled and the speed at which the processing of the intelligence is taking place. The bottom line is that rather than having to tune through each RF frequency one at time, as you have to with a conventional Superhet radio, the SD Radio can tune and process multiple frequencies at one time and gather the intelligence of each frequency even within multiple modes of communication. Quite simply, SD Radios have rendered all analog Superhet radios obsolete, just as the Superhet radio rendered all tuned radio frequency (TRF) radios obsolete when that technology was invented 87 years ago.

Even if all an SD Radio could do was receive, it'd still be pretty impressive. But it can also transmit by performing the same processes in reverse. Starting with whatever intelligence you want to transmit (again, it can be voice, text, or data), the SD Radio processes the information using an appropriate software algorithm, modulates it through digital processing, converts the digital signal to an analog RF signal, and then amplifies it using a broadband amplifier. Even more important is that thanks to the computer software creating virtual circuitry, the size and power consumption of this unit for both transmit and receive is several orders smaller than anything you've ever seen. And this is only the beginning!

Don't forget, we're still just in the *early* development stages of this exciting new technology.

And That's Not All—It's Adaptive!

So what you have with an SD Radio is the capability of simultaneous reception and transmission taking place over multiple frequencies using multiple modes by multiple people. More importantly, by using a computerized system, the radio is more than simply a way of sending and receiving information, because being computerized, the radio is capable of being adaptive. I'll be getting into how this adaptability works at the software and hardware level in an upcoming column in this series. For now, however, the key point is that through this adaptability function an SD Radio unit can perform a wide range of activities which are completely impossible for a conventional analog radio (such as transforming itself into another radio on the fly).

Here's a scenario to demonstrate how SD Radios differ radically from conventional radio systems:

Let's say that it's about five years from now (maybe even sooner) and we're at the headquarters of a national safety organization that manages events during natural disasters. Rather than having multiple handheld radio units sitting in battery chargers waiting to be used, there are what appear to be radio components sitting on shelves in a storage area.

A disaster occurs, such as a flood, and the person in charge of setting up radio communications begins to put together the radios that are needed for the specific task. Starting with the body, the radio specialist clips on a RF front end, antenna, and specialized modules that are appropriate to the activities that are to performed by various personnel. After turning on all the radios so their internal computers boot up, a wireless computer network immediately transfers individual software to each unit. This software contains all the frequencies the emergency personnel are going need for this occasion, as well as the modes under which the radios will be operating. Detailed maps, lists of personnel, individual duty rosters, and other pertinent information is downloaded at the same time.

When everyone on the emergency team their radio, it immediately provides them will all the information required to do their jobs effectively. A Global Positioning Module incorporated in the radios will allow each member of the team to see where every other member is on a map of the area. The radio itself is small enough to fit on a belt, with the video-capable data display located on a the wrist, much like the old Dick Tracy radio of comic strip fame.

Again, everything I am talking about is already on the shelf or at least on the drawing board getting ready to be put into production. This is neither science fiction nor speculation, but hard fact that will transform the way radio is going to be used. At this point we are seeing the slow but steady transformation of the radio communication infrastructure, beginning first with the military and then slowly moving down through the various public safety agencies, starting with the state

police and various municipal based agencies. Finally we will begin to see SD Radios move into the public sphere as public communication systems, such as cell phones companies, begin to switch over. At that point, your cell phone will be replaced by something that will not only provide you with voice communication, but also open the front door of your house, start your car, open the garage door, get you into your office, and pay for the soft drink you get out of a vending machine. The biggest issue here is the cost, both in terms of research and development, and then deployment. The fact is that there are billions of dollars of existing radio communication equipment out there that's working just fine, but it could be improved upon. As with all new inventions, what appears fantastic today will be commonplace tomorrow. How many electronic gadgets do you have that you now take for granted (but couldn't live without) that were once the great new thing?

Yes, it's a little bit disconcerting how many tasks an SD Radio will be capable of beyond voice communications. What you'll be holding in your hand will be more like an electronic Swiss Army knife than a walkie-talkie, only with more tricks, attachments, and accessory paraphernalia than you could ever imagine.

Next Month: You Can't Get Any More 21st Century Than This!

Okay, you're probably asking "So just how do you make one of these SD Radios you've been talking about, Joe?" Luckily, that's what I'm going to be looking at in detail next month, giving you the schematics, so to speak. That will lead up to the following month where I will show you how to actually make such a device.

"Is it really that hard to actually assemble an SD Radio," you might ask next. Well it's definitely not for the beginner, but frankly you might be surprised at how much of this technology has been worked out already by other people, making it fairly accessible for someone who's willing to take their time and learn the basics I'll be outlining for you. I'll give you information on how to build the base unit as well as how to connect it to the antenna and the computer. After that I'll give you a list of free downloadable software you will need to run your radio, both in the base unit and the computer. This is exciting stuff and everything I'll be writing about is now on the very leading edge of computer-assisted radio monitoring. You can't get any more 21st Century than this, my friends!

For those of you who may be a bit intimidated by computers and technology, in the fifth column of this series I'll be looking at true SD Radios designed specifically for radio monitoring that you can buy off the shelf right now. You'll be surprised at how far we've come already to "plug and play" modules. After that I'll also take a good look at the legal and political issues surrounding SD Radio, which have some very important implications for the future of the radio-monitoring hobby in the digital age. So be prepared for a very interesting journey.

As always, I'm interested in any pictures you may have of your own computer-assisted monitoring station or stories about how you have built and run it. You can contact me via e-mail with any submissions or questions at carm_popcomm@hotmail.com. While I can't answer general questions on computers, I'll be more than happy to help you with any issues raised in the columns. You can also write to me at "Computer-Assisted Radio Monitoring," PMB 121 - 1623 Military Rd., Niagara Falls, NY 14304-1745. Also, on my personal webpage (www3.sympatico.ca/joe_in_ey) you'll find a list of the columns I've done over the past two years, along with a summary of the content, and instructions on how to purchase back issues of *Popular Communications*. Remember that I cannot release previously published material as *Pop'Comm* owns the copyright.

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See you again next month! ■

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by Joe Cooper, carm_popcomm@hotmail.com

Software-Defined Radio—Part III How To Build An SDR, The Hardware Component

Over the past two columns I've introduce you to a revolution currently taking place in digital radio technology that is in every way just as important as the invention of the Super-Heterodyne radio. Frankly, you can throw in the invention of Radioteletype, FM radio, TV, and even single-sideband into that statement as well. The revolution I'm talking about is Software-Defined Radio (SDR), the development of which the U.S. military is currently underwriting through an investment of $25 billion through the JTRS (Joint Tactical Radio System) initiative.

To understand why the military is so excited about this new technology, consider that a standard SDR literally represents a single black box of radio equipment that's about the size of a bar fridge. This black box not only replaces a truckload of transceivers, but you don't have to patch together different equipment into a working system. This one black box is able to support multiple modes (up to 33 waveforms including several cell phone modes) of transmission and reception over a frequency range of 2 MHz to 55 GHz. The beauty of such a system, other than its small size and ease of integration into complex operating environments, is that you can re-define its features and functions simply by re-writing the software code placed into it.

The bottom line is that the actual *hardware* component of the radio system remains constant and relatively unchanging over time, thus reducing costs and maintenance. Meanwhile, the actual circuitry, which exists in virtual form within the software component of the radio, can be constantly updated and refined.

You can see then why the military would find SDR so desirable. Because one SDR can manage multiple waveforms over an extremely wide band of frequencies, the need for rooms full of multiple radios in racks is eliminated. The hardware component, being small and needing only the occasional upgrade, could be installed in a semi-permanent way in tight, highly protected areas of ships, planes, or vehicles. Think of what this would mean for submarines, tanks, or troop carriers where space is at a premium.

While the military may be getting the best toys first, that doesn't mean that the civilian sector is going to have to wait indefinitely for this new technology to become declassified. The fact is that the hardware components of SDR technology are already available in "off-the-shelf" commercial products that can be used by the radio monitoring hobbyist and radio amateur operator with relative ease. More importantly, there's an active group of people who are working together to develop non-profit hardware and software SDR technology. Further ensuring that SDR technology will be accessible is that the development platform is LINIX based.

So far this work has created affordable hardware technology, along with free software available for download on the Internet. Welcome to radio in the 21st Century, where circuits are built using computer keyboards rather than soldering irons.

This month I am going outline the hardware requirement for creating a homebrew SDR, which will lead us into setting up the software component next month. Now, I must warn you that getting into SDR at the hobby level is not cheap, but you'll find that the equipment that exists today is well built and supported and comes fully warranted. This technology also has crossover capability into a wide range of electronic test equipment, such as multimeters and oscilloscopes. So whatever investment you do make will pay off as you build up your experimenter's toolbox, not to mention your technical knowledge.

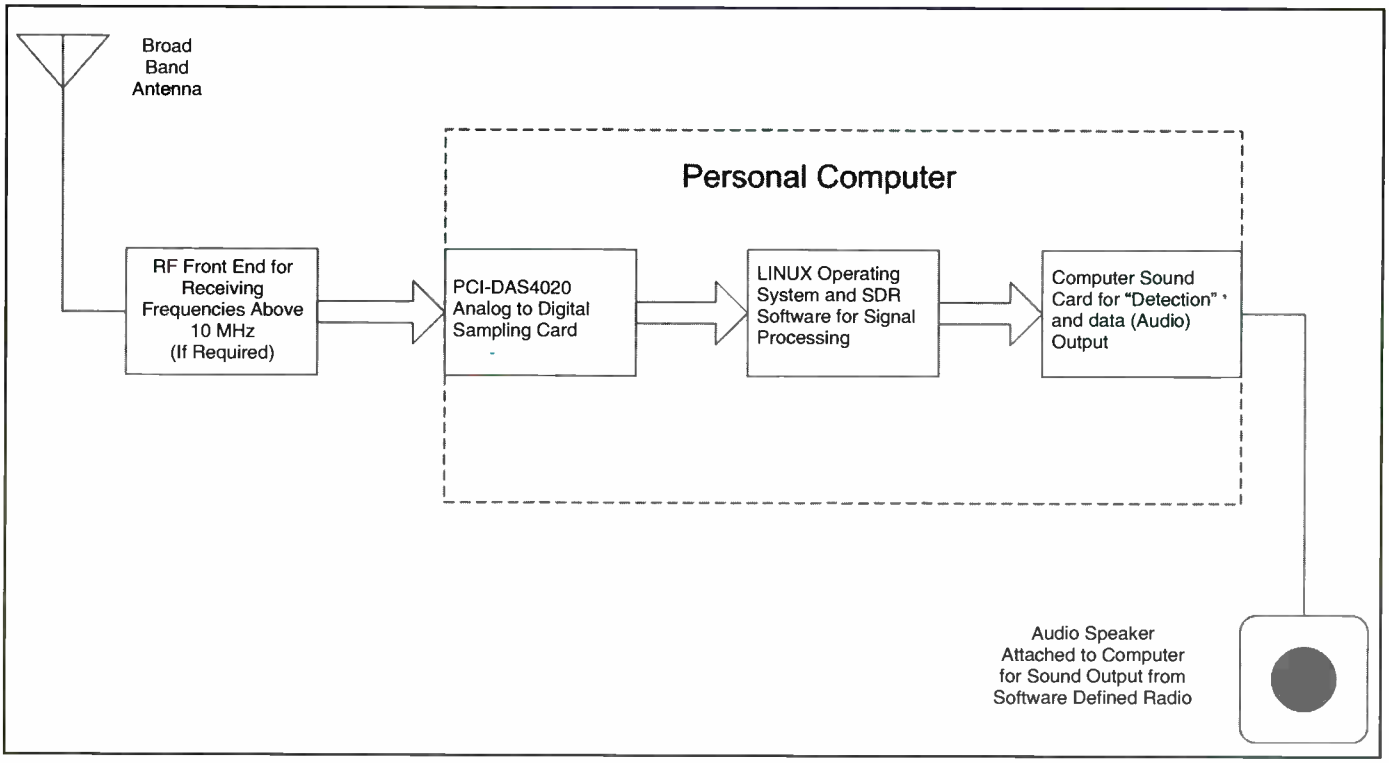
Before delving into the hardware, however, let's take a quick look at some more of the theory behind SDRs (for additional information, refer to last month's column). Keep in mind that while the theoretical background for an SDR is rather complicated, the actual construction and operation of one is not.

Digitally Sampling RF Signals

What makes an SDR special is rather than having to tune through each RF frequency one at a time (as you have to with a conventional Superhet radio), the SDR can tune and process multiple frequencies at once, gathering the intelligence off each frequency even while using multiple modes of communication.

What's the difference between sampling and tuning, detecting and processing? First let's look at the difference between making a digital sampling and an analog recording. We'll start with one of the most common forms of digital sampling: the creation and use of a music CD.

When you play a music CD in a CD player it produces an electronic signal. However, rather than being the complex sine



This block diagram illustrates the essential components of a Software-Defined Radio (SDR). The RF front-end converts selected frequencies in 10-MHz bandwidths, which the analog-to-digital sampling card can process (if you're monitoring frequencies between 0 and 10 MHz you don't need the RF front-end at all). The sampled information is then processed by computer, which creates the virtual electronic circuits using the SDR software. This processed information is sent to the computer's sound card, which converts it to an audio output (if required) heard over a loudspeaker plugged into that card.

wave of an analog device like an old-style LP or 45 record, the signal is represented by a series of zeros (0s) and ones (1s). The digital audio file that has been placed on the CD was created through "sampling" an analog sound signal by using computer hardware and software to converts each sample into those sequences of digital numbers (0s and 1s to be precise).

There are two important components to this sampling: the sample rate (the number of times a sample takes place over a fixed period of time) and the bit depth used in that sample (the amount of information captured in each sample). With some digital recording software you can control the sample rate and the bit depth, so it's important to understand what these components are and how they're used.

The sample rate determines the highest frequency that can be captured from the analog signal. As a rule of thumb, the highest frequency that can be preserved when making a digital recording from an analog source is always less than half the sampling rate. Therefore, the 44.1-kHz sample rate used by CD audio can capture frequencies up to about 20 kHz. If you sampled at 32 kHz, the upper audio range is reduced to rough 16 kHz. If you went all the way down to 4 kHz, the upper audio range would be about 2 kHz. The sine wave is actually still there because it's sound that's being moved through the computer circuits. However, rather than the actual sounds, it is a numeric representation of the sine wave using the 0s and 1s to represent it.

This leads us to the next question: How can you sample something like radio frequencies? It's all very well and good to talk about sampling frequencies in the range of 2 to 20 kHz, but how do you do that when you're talking about frequencies in the megahertz and gigahertz? If you go back to the figures for CD audio sampling, you'll see that a 44.1-kHz sample rate allows you record up to 20 kHz. This follows from a mathematical formula, known as the Nyquist Rate Equation, a foundation for the theoretical basis of digital sampling.

Developed in 1927 by the Swedish-born electrical engineer Harry Nyquist during studies he was conducting on analog-to-digital conversion techniques, this formula states that in order to be able to sample a given signal, the sample rate must be twice as fast as the bandwidth of that signal. Put simply, if you want to be able to sample signals up to 1 MHz, your sample rate would have to be 2 MHz. Likewise if you wanted to monitor up to 2 MHz, you'd have to sample at a rate of 4 MHz. As you can see, as the frequency you want to monitor goes up, the sample rate required keeps doubling. We'll see in the next section that this has a tremendous impact upon the amount of data you're asking the computer to process. Things are made even more complicated because of the presence of harmonics and other phenomena in a sampled signal, so you begin to run into some real problems with the sample itself.

The best way to explain what happens in an SDR when sampling occurs is through the example of another method of analog-to-digital sampling: the motion picture camera. When you make a movie you're not making a record of every moment that takes place before a camera. Rather, the motion picture camera takes a series of samples, in the form of discrete pictures, of the events that are happening before the lens. When the film is developed and played back through a projector, our brains are able to make the sampled images move as if an uninterrupted flow of events were taking place in front of our eyes.

However, not everything that is photographed using a motion picture camera

will present itself as flowing smoothly through time. A good example of this can be seen in a Western, where the spokes of a wagon wheel appear to be going backwards. This is because the sampling rate of the motion picture camera is too slow to capture the true position of the spokes on the wheel. Such sampling phenomena are experienced with an SDR in the form of phantom signals, distortion, and "dead signal holes" in certain ranges of frequencies. Fortunately, with proper filtering, the use of a proper sampling rate, and other techniques, these problems can be eliminated.

So, how do we use this theory to actually build an SDR? It's actually fairly straightforward, using off-the-shelf equipment, as we'll see now.

Basic Equipment Set-Up

To put together a true SDR, you'll need four basic components:

- Broadband antenna with coax lead to computer
- High-speed data acquisition card
- High-speed PC using the LINIX operating system
- High-performance sound card

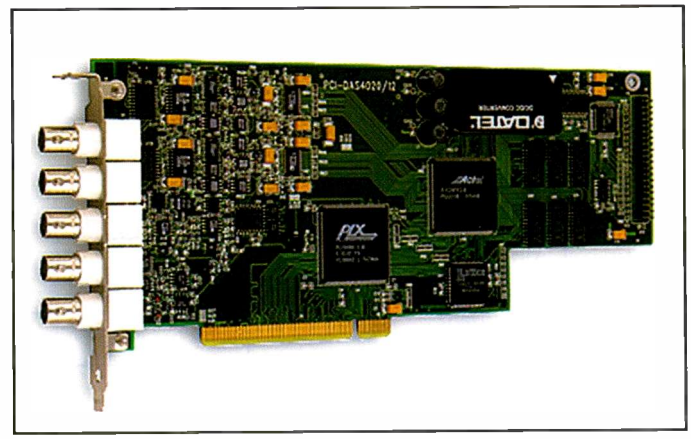
Frankly the antenna does not have to be special; most people simply use either a long wire or dipole antenna for frequencies below 30 MHz, or a discone antenna for those above the HF band. The coax lead-in from the antenna is attached directly to the data acquisition card, which I will get to next.

The data acquisition card, or DAC, is essential for the success of the project. It's built into a computer card that's plugged into an open accessory slot on your computer's motherboard. Fortunately today's computer equipment is "plug-and-play," and all you need to do is put the card in and turn the computer on. The DAC and the computer will then have a little chat, get to know each other, and do the entire configuration themselves. Next, you simple hook up the antenna's coax directly to the DAC using the coax connector in the card itself. Now all you have to do is run the software that defines the radio, and then detect your signal via the computer's sound card.

The key thing to understand is that the purpose of the DAC is to take samples of the voltages generated in your antenna when radio waves pass through it. The card then converts the voltage information into a digital form, which the computer can process. You must realize, however, that sampling the information contained in RF frequencies is going to produce a lot of data for your computer to detect. Let me give you an example.

One of the most popular DACS in use for SDR today is the PCI-DAS4020 made by Measurement Computing of Middleboro, Massachusetts (www.measurementcomputing.com). It costs $1,300 from the manufacturer, and while that may seem a bit steep, consider that you get a lifetime warranty with unlimited technical support, plus other benefits. Also consider that you can purchase software from third party vendors that will allow you to use this DAC to turn your computer into an oscilloscope, a multi-meter, a spectrum analyzer, a strip chart, and many other data recording devices. Frankly, if you're a serious electronic or computer experimenter, this rather modest investment gives you lots in return.

Measurement Computing's DAC is capable of an analog-to-digital sampling at a rate of 20 MHz, with each sample 12 bits long. Doing the math, you find that the board can produce 40 MB of data per second! Consider for a moment that in the early 1980s the average PC hard drive held a total of 20 MB of data; today we're asking a computer to process twice as much in one second! Fortunately the CPUs in today's PCs can process that amount of information with little problem, and the coupling of these DACs to a good PC has made SDRs possible.



This is Measurement Computing's PCI-DAS4020 ultra high-speed analog-to-digital converter that makes a PC-based SDR possible. It has four analog inputs that you can hook up directly to an antenna for reception between 0 to 10 MHz, or you can put an RF front-end between the card and the antenna to receive other frequencies in 10 MHz bandwidths. The card is 100-percent plug-and-play and comes with an impressive support and warrantee package. (Photo courtesy Measurement Computing)

Using the Nyquist rate equation, we see that since the total bandwidth that can be sampled is equal to one-half the sampling rate, the upper frequency limit of the PCI-DAS4020 is about 10 MHz. Now if the frequencies you want to listen to are all located below 500 kHz, the broadcast band and the lower end of the shortwave radio bands, then this setup is perfect! However, what if you want to want to listen to frequencies above 10 MHz? How could you use an SDR to listen to broadcast FM, scan public service bands, or watch television?

Well, the answer to that question is also fairly straightforward. You need to build a converter that will take a 10-MHz block of frequencies in the range you want to monitor and convert them down to the 0- to 10-MHz range. This is an old technique that used to allow ham radio operators to listen to VHF and UHF stations over their conventional HF monitoring radios.

So, in reality, what you find with most experimental SDR radio designs today is that they're a mix of a Superhet RF front-end with an IF bandwidth of 6 to 10 MHz. If you want to keep your costs to a minimum, you can use the DAC by itself if you simply want to listen to conventional BCB and shortwave stations. Next month I'll introduce you to some additional core SDR equipment that you can either build or purchase.

The bottom line with SDR is that this is now *the* radio technology of our age—everything that came before is obsolete.

Coming Next Month

Now that we've talked about capturing signals, how does the computer detect them so we can listen to the information being

transmitted? This brings us to the software that processes the digital information captured by the DAC, after which it is sent to the computer's soundcard to get the audio out to the speakers. Obviously SDR is not limited to audio output alone. If you are going to be viewing video information, you would need a special video tuner card, which I'll discuss in the next column as well.

Due to its relative complexity I'm going examine the actual installation and setup of the software for SDR in full detail next month. There's no off-the-shelf software available at this time to help you create a SDR using the Microsoft Windows operating system (at least that I know of). If you're going to create an SDR you are going to have to work within the LINX operating system, and that requires some special installation techniques. However, on the plus side, most of the software that is available is free, so you can take some solace in that.

As always, I'm interested in any pictures you may have of your own computer-assisted monitoring station or stories about how you have built and run it. You can contact me via e-mail with any submissions or questions at carm_popcomm@hotmail.com. While I can't answer general questions on computers, I'll be more than happy to help you with any issues raised in the columns. You can also write to me at "Computer-Assisted Radio Monitoring," PMB 121 - 1623 Military Rd., Niagara Falls, NY 14304-1745. Also, on my personal webpage (www3.sympatico.ca/joe_in_ey) you'll find a list of the columns I've done over the past two years, along with a summary of the content, and instructions on how to purchase back issues of *Popular Communications*. Remember that I cannot release previously published material as *Pop'Comm* owns the copyright.

Please also remember our troops overseas and give them your support. While the "Any Service Person" mail program has been suspended for security reasons, you should visit the U.S. Department of Defense's official webpage, "Defend America." They have a section, found at http://www.defendamerica.mil/support_troops.html, which provides an amazingly wide range of practical and useful ways that you can directly help. Please take some time to check out the resources suggested on that webpage and put them to use.

See you again next month! ■

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by Joe Cooper, carm_popcomm@hotmail.com

Software-Defined Radio—Part IV How To Build An SDR, The Software Component

As I've outlined in the past three columns, we're currently in the early stages of a technological revolution that's radically changing the way radio receivers and transmitters are being designed and built. This revolution has come about because of the availability of cheap and easy-to-use computerized components that allow engineers to create "virtual" radios through software programming. As a result, this new technology has come to be known as Software-Defined Radio (also referred to as SDR or SD radio).

SD radios operate in a way that is significantly different from the conventional (or Superhet) receiver that is currently the most popular receiving radio design. The primary design feature of the Superhet is that all frequencies that are received are first converted to single frequency, then amplified and detected.

What makes the SD radio different is that rather than taking one frequency off an antenna and converting it to a single frequency, the SD radio amplifies *all* the frequencies from an antenna over a very wide bandwidth and then converts *all signals found in those frequencies—man-made and natural*—from analog into digital form.

So, to use the proper terms employed with this new technology, an SD radio *samples* a broad bandwidth of the RF spectrum as it is received at the antenna, then digitizes it. Then, rather than simply amplifying one signal, an SD radio uses Digital Signal Processing (DSP) to *process the entire bandwidth* contained in the digitized sample of the RF spectrum.

Next, the intelligence (or information) found anywhere within the digitally sampled RF signal can then be detected using special DSP algorithms. More importantly, more than one source of intelligence can be detected at a time, allowing multiple stations to be monitored simultaneously.

Once that has been accomplished, the SD radio can then pass one or more sources of intelligence found in the sampled RF signal to any number of digital devices. Once that has been done, that information can then be displayed or converted into analog modes, such as video images or audio sound.

It's Really Not That Difficult

What's really interesting about this new technology is that while what can be accomplished with it can be very complex, the hardware requirements for an SD radio are actually very simple. In fact, most of the required components are available off the shelf and at reasonable prices.

To make an SD radio, all you really need is a broadband antenna, a good high-speed personal computer, a data acquisition card (DAC), and a computer sound card in order. You simply attach the antenna to the DAC, which then "samples" the voltage of the RF spectrum that it finds on the antenna. This sampled information is then processed through virtual radio circuitry created through DSP software running in the computer. Once the sampled signal is processed (which includes filtering and detection) it is turned back into an analog signal in the computer's sound card so it can be heard or passed on to another software program where it can be used to display text or graphics, depending upon the signal source.

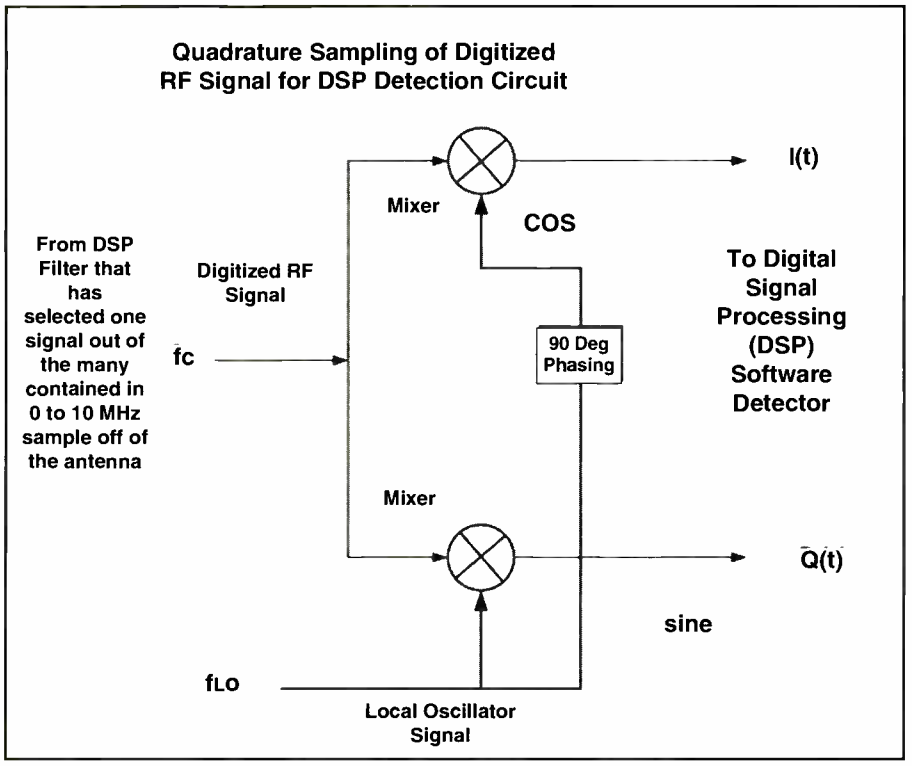
The Simplicity Of SDR

There is still a lot of experimentation and discovery taking place within the development of SDR at both the professional and hobbyist levels, although most of the mathematics providing the theoretical foundations were actually developed during the 1930 and '40s. In fact, one of the first electronic digital sampling devices was created in the late 1940s at the Research Laboratory of Electronics (REL) at MIT. During the 1960s and '70s this same group created some of the first virtual DSP circuitry using their TX-2 computer.

Interestingly, the first commercial experiments in DSP were undertaken in the 1950s by the oil industry in processing seismic data to find oil and gas deposits deep in the Earth. The broad commercial use of DSP technology emerged in telephone communications technology during the 1960s, with the development of the T-1 digital carrier system in 1962.

Later, thanks to the introduction during the 1980s of inexpensive high-speed CPUs and complete computers on a chip, such as Texas Instrument's TMS32010 and the Motorola 56000, it became possible to develop mass-produced DSP devices as consumer products. When this was combined with the development of the relatively low-cost personal computer with its high performance CPUs, a series of major breakthroughs in SDR technology began emerge from the laboratories, beginning in 2000. This trend has continued to this day.

We're now in a unique point of convergence where varied technologies, such as the Internet, high-speed digital communication and personal computing have reached a level of power and affordability that has placed SDR technology within the reach of the radio hobbyist. This has been brought about in great part due to the infusion of billions of dollars in research into SDR by the U.S. military, the benefits of which have trickled down to the general population. Today, SDR technology at the hobbyist level is in a



This diagram shows the digital mixing circuit used to create the Q and I products necessary for a DSP-based detector to work.

period of technological transition, with many designs being a hybrid of Superhet, DSP, and SDR.

Early design attempts have used an external hardware-based RF front-end that provides tuning and detection to a single IF frequency, which then is digitized for processing in a DSP circuit. However, the ultimate goal of many involved with the hobbyist design of SD radio is to make the design as simple as possible. To do this, they are attempting to eliminate the RF front-end where the tuning of the signal takes place, and replace it with an analog-to-digital (A/D) converter that will sample a wide bandwidth of radio signals directly off the antenna.

The primary reason this minimalist approach to SDR design has not been widely undertaken is the lack of A/D converters with sufficient bandwidth to sample radio frequencies properly. However, this situation is changing, thanks to the introduction of the PCI-DAS4020 A/D card, which has provided the hobbyist and serious experimenter with an affordable "plug-and-play" device to place into their personal computers. This card can sample RF signals up to 10 MHz, allowing for the creation of a simple SD radio that will directly "tune" the LF, broadcast, and lower part of the shortwave band.

However, if you're willing to forgo the plug-and-play capability of PCI-DAS4020 you can experiment with a newly developed A/D converter from Analog Devices, the AD9430. This particular A/D card uses the fastest chip technology available today on the civilian market with a sampling rate of 210 MSPS (mega samples per second) with 12-bit resolution. More importantly, it has a bandwidth of 700 MHz, which will provide more than sufficient coverage of all of the LF, HF, and VHF frequencies that are popular with the amateur radio and monitoring hobbyists.

The big drawback with this particular card, though, is that it requires a solid background in engineering in order to get it to work. However, sometime in the very near future, someone with the time, money, and experience will tinker with it enough to make it an exceptionally wideband SD radio that will be suitable for the hobby market.

Getting The SD Radio To Work

So, assuming that you've installed the easier to use PCI-DAS4020 into your PC and hooked up your antenna to one of the input leads on the card, how do you "tune" it to monitor a particular frequency and then listen to what you find there? The answer is that you'll need some sort of tuning, detecting, and processing software installed in that computer, along with a device in the computer to convert digital information back to analog so that you can listen to it. Luckily, that A/D converter is something that nearly all personal computers have today: a computer sound card. If you've ever played music or sound through your computer's speakers, then you've been doing A/D conversion (and probably didn't even know it).

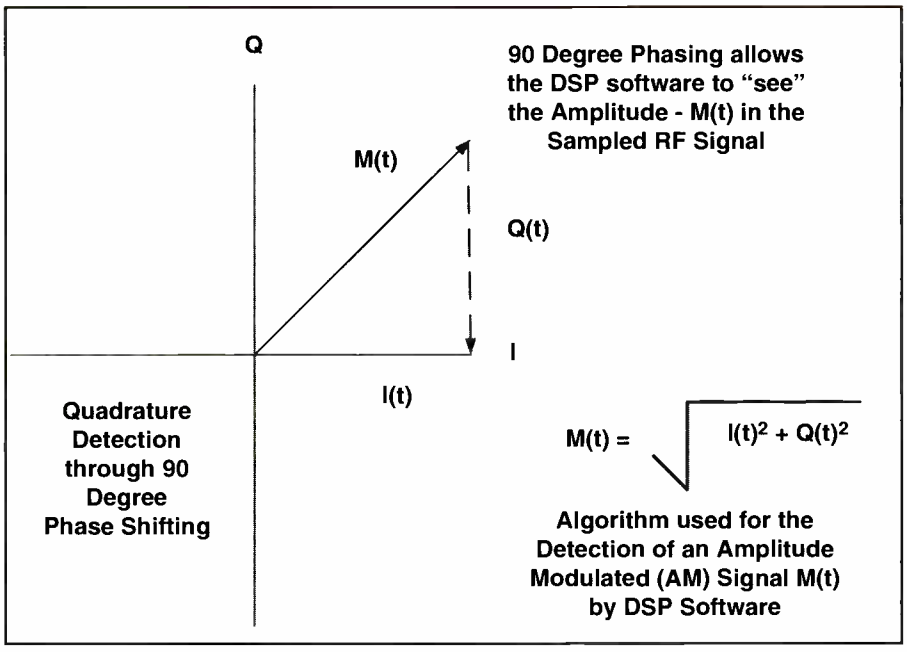
Let's look at the software component of a personal SD radio. Now I don't promise to turn you into a computer programmer by the time you finish reading this, but you'll at least have a good idea of the theory involved and main components used to "build" such software.

Fortunately you can download from the Internet a fair amount of the software you need to create your own SD radio, thanks to the extensive amount of work done by computer geeks and dedicated radio monitoring experimenters. I hope this column will inspire you to try building an SD radio yourself, or at least to learn more about this fascinating technology. Frankly, it's really not all that hard once you set your mind to it. But first you'll need a plan to guide you, and that's what I intend to outline for you here.

DSP Fundamentals

DSP is really very simple technology, but as with any simple technology, a lot of thought had to go into it to make it the way it is. An SDR really only performs three tasks: 1.) converts analog RF signals to digital data; 2.) processes that digital data so that the information it contains is tuned and detected in order to release the intelligence (music, speech, data) contained within it; and 3.) converts the detected intelligence from digital into analog form so we humans can understand it. All that's taking place within the computer to create the SD radio is something that is already well known in radio monitoring: DSP.

Today DSP technology is in use all around us, in sound cards, fax machines, modems, cellular phones, high-capacity hard disks, and digital TVs. (Here's an interesting bit of trivia: the first commercial DSP chip ever used was in Texas Instruments' "Speak & Spell" game from the late 1970s.)


Q
90 Degree Phasing allows the DSP software to "see" the Amplitude - M(t) in the Sampled RF Signal
M(t)
Q(t)
I
I(t)
Quadrature Detection through 90 Degree Phase Shifting
M(t) = √(I(t)² + Q(t)²)
Algorithm used for the Detection of an Amplitude Modulated (AM) Signal M(t) by DSP Software

When the phased signal is sent to the DSP detector, it is able to determine the amplitude M (t) of the RF carrier as the product of an algorithm. Shown here is the formula used to determine the amplitude of the intelligence (music, voice, or data) contained in a digitized RF AM carrier. Other mathematical formulas are used in the detection of intelligence in other modes of communication. Once that value is determined, the DSP software can pass the result to the computer's sound card, where it is turned back into an analog signal that can be heard through speakers or earphones. This same information can also be used in other software programs to produce text or graphics.

Even if you're not interested in building an SD radio, you can still take a listen to DSP if you have a sound card installed in your PC. If you check the software that comes with that card, you'll most likely find that it can simulate the sound of a concert hall or create pseudo-surround sound when you play a music CD with your computer's CD player. That ability to change the original sound into something else is done through the processing of that digital information. This is accomplished through rapidly performing mathematical calculations on digitized signals that were originally analog in form (that is, voice or music).

There are many advantages to using DSP over conventional electronic circuits. Quite simply, electronic components are relatively large, take a fair amount of power to operate, and their values (resistance, capacitance and inductance) can change due to ambient temperature, age, and even just being bumped. However, DSP circuitry, because it is virtual, is not subject to any outside influences. It is simply comprised of mathematical equations, which are consistent under any and all conditions. This makes DSP ideal for any situation where dependability and predictability are critical.

While these dependability and predictability factors are important, the primary reason DSP circuitry is so valuable is the programmability of the processing that takes place within it, allowing a number of parameters to be easily changed. I outlined a good example of this particular virtue of DSP circuitry in my series on Ten-Tec's RX-320 computer-controlled radio. One particularly powerful feature of the RX-320 is that it offers 34 IF bandwidths, ranging from 300 Hz to 6000 Hz, with the click of a mouse button.

Think about that while remembering what it used to be like to change bandwidths on older analog radios. With those old radios you may have had only four bandwidths to choose from; one for each mode the radio received. When you changed a bandwidth, you had to turn a mechanical switch, which was connected to various coils and capacitors. If you wanted more bandwidths, you needed more component space. Frankly, with all those mechanical devices, the actual results were not that good, unless you used a lot of very expensive components.

But, through the use of mathematical calculations via the software in the DSP circuitry, the RX-320 can serve up its 34 values within an electronic component that is roughly one-inch square. The point of all this talk about DSP is that it is the heart of the SD radio.

When you create an SD radio all you're doing is turning your personal computer into an advanced digital signal processor that has several additional functions. Those functions include the ability to direct the flow of digital information from the A/D card to the computer sound card and to detect the intelligence found within the sampled and digitized RF signal being passed between those two devices.

So how is this done?

"Building" The SD Radio In A Computer

When you use DSP technology you can create a virtual electronic circuit by describing the function of a virtual electronic component as a mathematical formula. Since an analog signal that has been converted into digital form is represented as a series of numbers, those numbers can then be processed through those mathematical formulas, with the result being the digital signal that will be changed or modified in the same way as an analog would be if it were passed through a "real world" circuit.

Conventional DSP circuitry has been successfully representing resistors, capacitors, and inductors in virtual form for many years now, and most of us have been using such circuits in our radio monitoring on a regular basis. Most of the time, though, that type of DSP has been applied to *audio analog circuitry*, so how do you then apply that to sampled RF signals? More specifically, how do you then "build" a detection circuit so you can demodulate AM, FM, SSB, or CW signals using DSP? It's not that different from the "real world" counterpart that would be used in a conventional circuit.

In its most fundamental form, radio is the application of a source of information (whether music, words, or codes) to a carrier wave that has been generated by electromagnetic forces that vibrate within a range we call "radio frequencies" or RF (roughly 10 kHz to well over 3000 MHz). A transmitter's RF energy, with this information contained within it, is released from an antenna out into the atmosphere. As this transmitted energy passes over other receiving antennas, they generate

internal voltages, which are then passed on to the radio receiver through a lead-in wire or coaxial cable.

In a conventional radio the RF voltages that enter the radio are passed through a tuning circuit which selects out a small set of frequencies while passing the remainder to ground. The low RF voltages of those selected frequencies are then amplified through any number of conventional techniques.

Once the RF signal is amplified, the next stage is to remove the RF component of the signal and to release from that signal the original intelligence that was placed on it. This is done through one of several methods of "detection," which can employ either a diode (solid state or a vacuum tube), a beat frequency oscillator and mixer (for CW or SSB), or through a discriminator circuit for FM.

In all of the above cases, the RF component is removed and the intelligence remains, which can then be amplified using audio amplification circuits. This intelligence can then be fed to an audio speaker, where it can be heard, or it could be used in other applications, such as radio teletype (RTTY) or telemetry circuitry to produce text or graphics.

This is all very fine and good, but how does this apply to our SD radio?

Here's the RFspace SDR-14, a 14-bit SDR receiver designed for the professional and advanced hobbyist. This unit samples the entire RF spectrum from 0 to 30 MHz and uses the same basic techniques to process sampled RF, as has been described in this column. Specifically, the unit converts sampled RF from its A/D converter into I and Q formats through phasing, and then sends the results to a PC via its USB port for detection using software algorithms and any further DSP processing that may be required. I will discuss this SD radio in more detail in next month's column. (Photo courtesy Universal Radio)

Tuning A Digital Signal

In the SD radio the antenna is connected to the A/D converter (such as the PCI-DAS4020 card) via one of the connectors on that card. The card, which is plugged into one of the expansion slots in a personal computer, samples the voltages found on the antenna over a frequency range from 0 Hz to 10 MHz and converts this analog voltage to digital information.

A software program running in the personal computer containing the A/D card captures the data streaming out of that card and then passes it through a virtual DSP circuit that it has "constructed." This DSP circuitry creates a virtual radio which can then "tune" the desired frequency that one wishes to monitor, and then demodulate the intelligence found on that frequency by using a virtual detector.

In some contemporary radio designs, such as Ten-Tec's RX-320, an RF front-end produces an intermediate frequency, or IF, that is roughly 6 kHz in bandwidth. This IF frequency is then turned into a digital signal which may be processed with one of a series of 34 DSP IF bandwidth filters that range in size from 300 Hz to 6000 Hz. In the case of a SD radio, you perform much the same filtering function, but instead of filtering a fixed frequency you use the same DSP filter to "look" at the full 10-MHz worth of digital information and then take a virtual "slice" out of one small 6000-Hz part of it (as an example) for further processing. Frankly, you could reduce that slice down to *300 Hz or less* if you wanted to, depending upon your requirements and software programming skills, and again take it out of any part of the sampled 10 MHz bandwidth you have to work with.

What's even more exciting about this technique is that you're not limited to only one "slice" (that is a single frequency) at time, such as you would be limited to with a conventional Superhet radio. Instead you can take multiple "slices" out of that sampled 10-MHz bandwidth and process them concurrently.

This technique of concurrent sampling and processing is already being used to great effect by the amateur radio community with computer-based software for digital modes such as PSK. Many software packages for communicating in the PSK mode allow you to hold multiple text-based conversations by simply pointing and clicking on multiple signal sources displayed on the computer screen.

The only things that limit the number of "slices" that can be used by the software is the processing power contained in the computer's CPU and the amount of data processing bandwidth contained within the computer's data bus circuitry. As it stands, the PCI-DAS4020 A/D card is pumping 40 MB of data into the data bus *per second*, which the CPU has to process along with running the software that's creating the DSP circuitry you're using, as well as all of the "housekeeping" tasks required just to keep the computer running. So each time you take a slice out of the 40 MB of data you're adding more "overhead" to the operation of the computer; if you add too much, the computer will begin to slow down and possibly even stop working.

The bottom line is that if you want to get the most out of your SD radio, you must have as much processing power as you can get. Most of today's computers that use a Pentium 4 or equivalent CPU running above 2-GHz clock speed will do you just fine. So just use some common sense if you decide to build your own experimental SD radio; you may find that the early Pentium series of CPUs just won't cut it.

Demodulating A Digital Signal

Once the software has chosen which "slice" of the sampled RF signal you will want to listen to, the intelligence contained within it, it will use it to generate text or graphics. This is accomplished by directing the "slice" of RF signal to a DSP demodulator circuit.

Frankly, I had to scratch my head a bit when it came to deciding how to describe the mathematical techniques used in making a DSP-based demodulator. I've decided to present the material about halfway between "trust me, it works!" and "don't you wish you paid more attention in your high school math class."

The starting point for any analog signal is the sine wave, which starts at a point of zero value, goes forward through time to a positive point, returns to zero, then goes through a negative point and returns to a zero value again. (What I just described

was one cycle). If the process is repeated, it's described in terms of cycles over a fixed period of time (such as per second). Sometimes when you are describing natural phenomena such as radio frequencies, those cycle measurements are given a special designation, such as Hz, MHz, and GHz to distinguish them from other cyclical phenomena, such as soundwaves (cps).

The only problem with this is that, while you can determine the frequency and amplitude with the information I just provided, it's difficult to know whether you are at the beginning, middle, or end point of the cycle. To determine that, you have to describe the characteristics of a sine wave using three properties: phase, frequency, and amplitude. The phase is a point in the cycle that is nearing either positive, negative, or zero; frequency is the rate of change of the phase; and amplitude is the maximum positive or negative value of the phase.

You are able to actually "see" the phase of a cycle by creating a virtual phase mixer within your DSP circuitry. With this device you can take the sampled RF signal and split it in half, with one half being held by half a cycle, and then remixing the out-of-phase sample with the original. This technique reveals the phase of a cycle through a mathematical algorithm, which allows for the detection of that phase at any given time. Once you have the phase information, you can perform an analysis of that sine wave as it passes through your DSP circuitry.

This phase analysis can be best explained by representing the sampled sine wave on a Cartesian graph, which has the horizontal axis labeled as *I* and the vertical axis *Q*. The mathematical algorithm calculates the instantaneous values of *I* and *Q* on that graph, providing you with everything you need to know about the sampled signal in order to detect the intelligence contained within it. Once you have this phase information, you can "build" a "virtual detector" in the DSP circuitry through the use of an appropriate mathematical formula.

To give an example, a virtual diode for the demodulation of an AM signal is constructed using a simple formula that calculates the sum of the square of the cubed products of *I* and *Q*.

The product of these calculations then represents the intelligence contained within the digitally sampled RF signal, which (after any additional DSP filtering required) is passed along to the computer's sound card, where it is converted back to an analog form you can hear through a speaker. (Trust me, it works!)

The Future Is Here

Again, this is the way of the future and, frankly, every single radio you now own that's based on conventional radio technology is already obsolete. At this moment, all services in the U.S. military are converting to SDR under the Joint Tactical Radio System (JTRS) Program, which is spending $25 billion to achieve that goal.

As I said at the beginning of this series, it's wonderful to be sentimental about all the great radio technology we used during the past 50 years, and I will always appreciate how enjoyable those experiences were. However, it's time to move on, because, if we don't, the radio monitoring hobby will be superseded by the general computer user community in the development of attainable and affordable SDR technology.

Next Month

So now that we've looked at the theoretical side of the hardware and software components of SD radio, how do you actually put one together? Next month, I'll tell you how to get your hands on those components and I'll provide as much primary source information as you'll need to get started, including more information on affordable A/D cards and the necessary software. And for those of you not yet brave enough to build your own SD radio, I'll show you where can you get your hands on one that's already been built and tested so you can try it out?

I will also provide you with information on those groups that are working together to advance SDR technology at the hobbyist level, as well as those who are trying to influence the FCC to prevent this new technology from being crippled by too many needless government regulations. Stay tuned.

As always, I'm interested in any pictures you may have of your own computer-assisted monitoring station or stories about how you have built and run it. You can contact me via e-mail with any submissions or questions at carm_popcomm@hotmail.com. While I can't answer general questions on computers, I'll be more than happy to help you with any issues raised in the columns. You can also write to me at "Computer-Assisted Radio Monitoring," PMB 121 - 1623 Military Rd., Niagara Falls, NY 14304-1745. Also, on my personal webpage (www3.sympatico.ca/joe_in_ey) you'll find a list of the columns I've done over the past two years, along with a summary of the content, and instructions on how to purchase back issues of *Popular Communications*. Remember that I cannot release previously published material as *Pop'Comm* owns the copyright.

Please also remember our troops overseas and give them your support. While the "Any Service Person" mail program has been suspended for security reasons, you should visit the U.S. Department of Defense's official webpage, "Defend America." They have a section, found at http://www.defendamerica.mil/support_troops.html, which provides an amazingly wide range of practical and useful ways that you can directly help. Please take some time to check out the resources suggested on that webpage and put them to use.

See you again next month! ■

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by Joe Cooper, carm_popcomm@hotmail.com

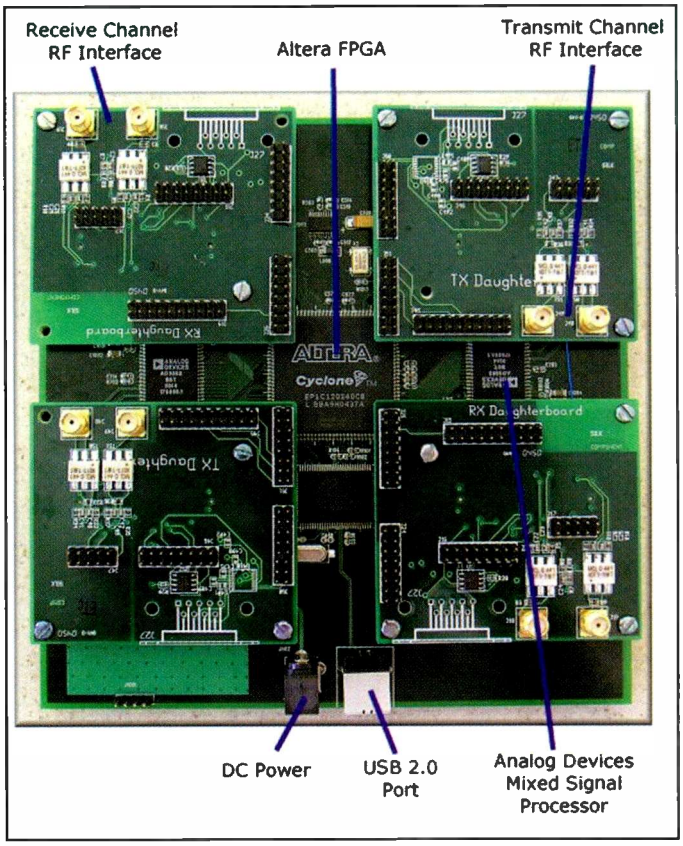
Software-Defined Radio—Part V
The Practical Use Of SDR: What's Available Today?

Over the past four columns I have outlined the theory of Software-Defined Radio (or SDR), which is promising to revolutionize the design of today's monitoring radios, whether they're intended for military, commercial, or consumer use. In this month's column I'll tell you where you can obtain the hardware and software components needed to begin experimenting with SDR technology yourself. I'll also outline for you the first generation of fully assembled SD radios that have been built specifically for the hobbyist market.

Today SDR technology is still in the pioneering stages (a good comparison could be made to where the amateur radio hobby was in the early 1920s) and a certain degree of technical knowledge is required to make this technology work. However, thanks to some significant advances made in the last two years, experimentation with SDR is not out of the reach of the casual hobbyist.

I hope those of you who have been following my column will come to enjoy the benefits of living in this truly amazing age by becoming active participants in this exciting new technology. One thing for certain, SDR will transform radio as we know it, just as the super-heterodyne radio, combined with mass-produced vacuum tube technology, transformed receiver design during the 1920s. SDR technology will certainly become integrated into the information revolution that began with the convergence of the Internet and personal computers back in the early 1990s.

What's even more exciting is that if you take the time to learn how to use this technology properly, you can have a front line role in creating this technology's history, just like Steve Jobs, Steve Wozinak, or Bill Gates did for the personal computer!



Here's the Universal Software Radio Peripheral (USRP), which has four daughterboards attached. In this configuration, the unit can both transmit and receive. Designed for use with software developed for the GNU SDR project, its primary function is to sample analog RF signals and then convert them to digital signals. All processing and detection takes place within a personal computer attached via a USB 2.0 interface. (Photo courtesy Ettus Research LLC)

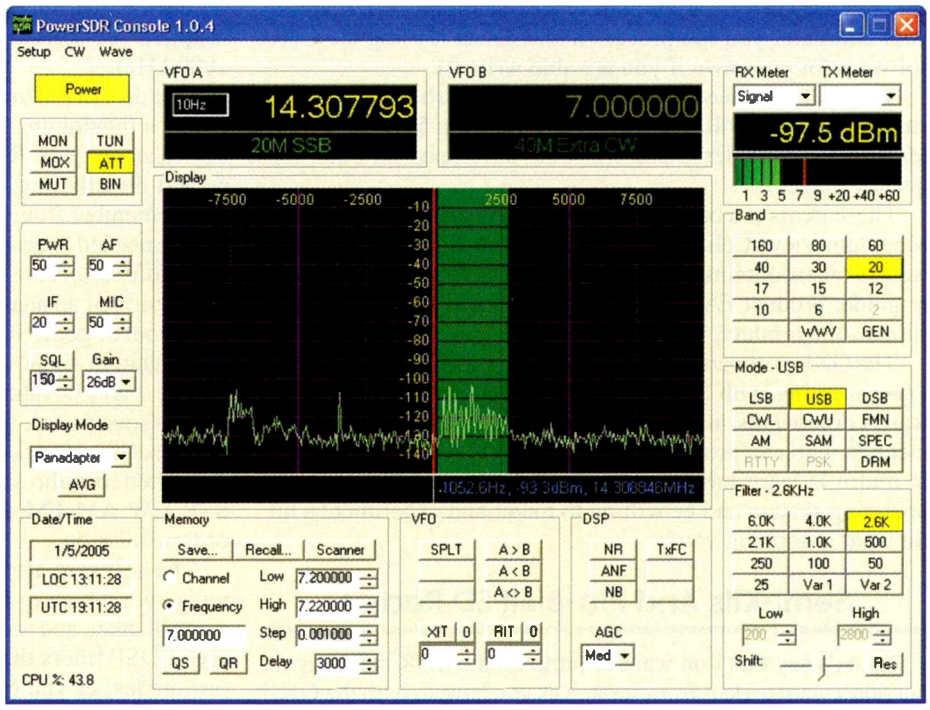
Before Getting Started—Learning New Skills

The first question you must ask your self before beginning to experiment with SDR technology is why you want to do so? While there is a great potential in this new technology, much of this is still to be realized through hard work and development on the part of the hobbyist community. If you do decide to become involved with SDR you may find that you're spending more time reading up on theory and tinkering with prototypes than on monitoring radio signals, just to develop SDR into a fully working technology.

To fully appreciate and use SDR technology properly you will have to develop a new set of technical skills, particularly in digital signal processing (DSP). Because you're sampling RF spectrum rather than tuning it, even the simple act of operating an SDR receiver will require a different set of monitoring skills than are used with analog receivers. One such skill to develop is how to set the proper sampling values in the DSP software used with your computer's soundcard so that it will work properly. In short, you may not have to put up with howling sounds coming out of your speakers as happened with a regenerative radio, but you may find that certain settings either produce no sound at all or sound that is distorted enough to qualify as a howl.

So again, what is it that you actually wish to accomplish by getting involved with SD technology? Is it simply the novelty of doing something new (which is legitimate) or do you have a specific goal to accomplish for developing your personal skill in radio monitoring?

The most important thing you need to decide on is the level of complexity at which you'll begin your experimentation.



This is the user interface of the PowerSDR Console software used with FlexRadio Systems SDR-1000. As you can see, it's set up for ham radio operation, the primary use for this SDR. It supports "point and click" tuning and control via a mouse, but you can also purchase a mechanical tuning knob that connects to the console software through the computer's USB port. It offers a general coverage receiver that tunes from 11 kHz to 65 MHz and is available as a stand-alone receiver in the SDR-1000/ROE version. (Photo courtesy FlexRadio Systems)

There's nothing wrong with buying prebuilt SDR equipment and simply learning to operate it well and then going on to more complex levels of understanding at a later time. But if you have a good background in using digital technology, by all means start out at the breadboard level and begin to prototype leading edge designs that will push the boundaries of the radio monitoring hobby.

So with that in mind, look at sources of hardware, software, and information that will satisfy the beginning experimenter through the expert who wishes to join the SDR revolution.

"Roll Your Own" SD Radio

There could not be a better time to get started in hands-on experimentation with SD radio than right now. Experimentation at the hobbyist level since 2001 has lead to the establishment of a fairly complete body of information that is easy to find on the Internet and in book form. More importantly, there is now a good supply of off-the-shelf" hardware and software components designed for the hobbyist. This will let you put together a working SD radio with minimal difficulty.

Even more encouraging is that there's a significant amount of the software you need for building an experimental SD radio that's available for *free* on the Internet, along with a fair degree of documentation to tell you how to use it. Now, having said that, the catch is that the majority of this free software is written in C++ for the LINUX operating system and requires a good understanding of how to perform basic programming in order to use it properly. While there is software available for off-the-shelf SDR equipment, much of it is still in the early stages of development and needs further refinement.

So at this point you have two choices: throw up your hands in despair or roll up your sleeves and take up the challenge of learning something new. The choice is yours.

In the upcoming year I'll show you free sources for legal copies of compilers (the software that creates computer software) for C++, Visual Basic, and other programming languages. I'll be doing this in conjunction with a series of columns on how to create your own custom user interface for use with popular software-controlled radios, including SD radios.

So why not make this year an interesting and challenging one for yourself—why not use SD radio as a way to take the plunge into computer programming and learning a computer operating system other than Windows? It will, without a doubt, require an investment of time and money, but you'll end up with a set of practical skills that will prove to be invaluable in this new digital era of radio monitoring.

The GNU SDR Project

If you're serious about creating your own SD radio from scratch, then head over to http://www.gnu.org/software/gnuradio/ to begin your journey. GNU (pronounced ghu-noo) was started back in 1984 and has an interesting history (which you should definitely take some time to find out about, given its significant impact upon the "free software" philosophy supported by many reputable software developers). The GNU software radio project was designed to encourage open public development of SDR technology through the sharing of ideas and software and by providing access to SD hardware.

The site provides all the software you need to "build" the virtual components involved in a fully functional SD radio. It also offers a series of documents that take you through the various levels of training needed to use the software. If you've read my previous columns on SD radio you'll find that the material presented there will come together very quickly.

In addition to the software component, you need some hardware to build an SD radio. As mentioned in the previous column, one of the most popular approaches is to use a data acquisition card that plugs directly into one of a PC's expansion slots and then attach it to an antenna. One of the easiest off-the-shelf products for this application is the PCI-DAS4020 by Measurement Computing of Middleboro, Massachusetts (www.measurementcomputing.com). The only problem is that it costs $1,300 from the manufacturer, and while that may seem a bit steep, the trade-off is that you get a lifetime warranty with unlimited technical support, plus other benefits.

Luckily, there's an affordable alternative, called the Universal Software Radio Peripheral (USRP), which was developed for use in conjunction with the GNU SDR software. The USRP costs a reasonable $450 and contains the necessary analog-to-digital (A/D) converters needed to build an SD radio. The USRP lets you direct the digitized RF signal into your person-

al computer via a USB 2.0 port. Once that digitized signal is in your computer you can process it and detect it using the GNU software (or your own if you are able write it).

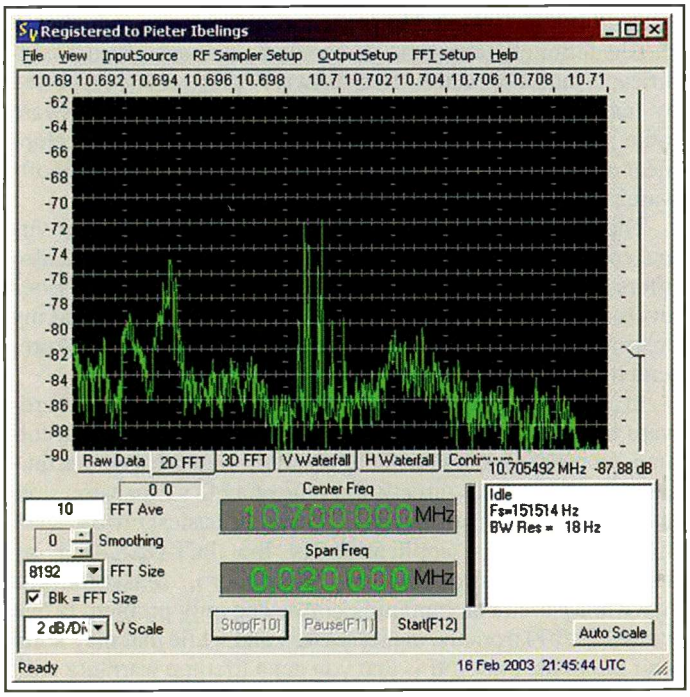
You will also need to purchase a daughterboard RF front-end for $50 that will enable you to tune from 50 MHz to 800 MHz; other daughterboards are being developed for other frequency ranges).

These items can be purchased online from Ettus Research of Mountain View, California (http://www.ettus.com/). The Ettus website also contains a downloadable USRP user and developer guide, product FAQ, and external links to user groups that support the product.

The GNU software project really is an excellent way to begin experimenting with SDR. It offers proven software and hardware components as well as a community of fellow experimenters who can provide technical advice. All you need to do in return is learn more about your computer and the LINUX operating system and be willing to tinker and experiment a bit. So what's stopping you?

Semi-Kits And Pre-Built SD Radios

So let's say that you want to jump on the SDR bandwagon, but don't want to do it from scratch as you have to with the GNU radio approach. But at the same time you don't want to simply buy an off-the-shelf SDR radio and just run it. At this time SDR technology is so new that there is only one semi-kit being offered for the radio monitoring crowd, but fortunately it's a very good one. This is the SDR-1000/ROE available from FlexRadio Systems of Austin, Texas (www.flex-radio.com). This represents the receiver section of the SDR-1000 ham radio HF transceiver. It is a fully operating general coverage and spectral analysis device that tunes from 11 kHz to 65 MHz (though a user supplied pre-selector is required for proper reception below 1800 kHz).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Blk = FFT Size
V Scale
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Idle
Fs=151514 Hz
BW Res = 18 Hz
Auto Scale
Ready
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The SpectraVue software, used with the SDR-14 by RFSpace, displays this console. While it doesn't offer as many functions as the software supplied with the SDR-1000, it still contains a number of impressive features. It's primarily designed for spectral display, which it does very well. The ultimate user interface for SDR is still waiting to be written. (Photo courtesy RFSpace)

One design feature that makes this SD radio interesting is its use of a quadrature sampling detector (QSD). This electronic device samples an RF signal at four times the carrier frequency and directly converts the signal to its *I* and *Q* values. You may remember from last month's column that those *I* and *Q* values are needed to detect the intelligence in the signal when using DSP software. This technique allows for the efficient digital conversion of an analog signal directly from antenna—the ultimate goal of good SDR technology design—with an accompanying gain in signal strength as well.

The *I* and *Q* values are sent via cables to a personal computer's sound card, where they are detected using a Windows-based software package (supplied with the SD radio) and then converted to audio sound. You can then listen to stations using SSB, CW, AM, FM, and DRM (Digital Radio Mondiale) modes of transmission.

The software also provides you with a wide range of DSP tools with which to process the signal, including notch filters, noise blanker, and noise reduction. Likewise, you can use a variety of DSP filters that come at either standard widths for various modes, or you can set up custom variable size filters that can be set to a minimum of 25 Hz.

If you want to take the rig out for a "test drive" in virtual mode, you can do so by downloading the free console software from FlexRadio System's website along with the pre-recorded audio files. You can then use these files to check out the DSP capability of the software while listening to actual signals captured by the SDR-1000.

The semi-kit comes with all circuit boards full assembled and tested and a matching enclosure, which you have to put together yourself. It costs $799, which is about $75 less than the fully assembled "receive-only" SD radio. You can also purchase an auxiliary USB-based tuning knob if you want to have a more "traditional" feel to tuning the SD Radio.

Hobby SDR's Leading Edge

If you want to go straight to a built-from-the-ground-up SD radio that's designed specifically for the professional and hobbyist radio monitor, you should definitely take a look at the SDR-14 by RFSpace of Lilburn, Georgia (www.rfspace.com).

Described as a FFT spectrum analyzer and digital receiver, the SDR-14 is a true SDR as the "box" is primarily a high-speed A/D converter, which converts a broad spectrum (0 to 30 MHz) of RF signals into digital data and then processes that digital signal into the required *I* and *Q* format using a direct digital converter (DDC). The *I* and *Q* digital data created within the SDR-14 are then sent to a PC via a USB 1.1 connection. All of the spectrum display and detection functions are then performed on the PC using the Windows-based DSP software that comes with the SDR-14.

The software package, called SpectraVue, supports USB, LSB, AM, FM, WFM, CW, CWr, and DSB, plus DRM with third-party software. This software works directly with the PC's sound card to process the DSP, allowing you to create a number of different filters and noise reduction schemes, and to convert it into audio sound.

One of SpectraVue's strongest features is its ability to display the analog data it samples as Raw I&Q, 2D and 3D graphs,

Continuum (power versus time), and two types of waterfalls. While each of these displays can be used to tune individual signals, their most impressive value comes in when the SD-14 is used for spectrum analysis: You can literally view every single signal between 0 to 30 MHz that appears on your antenna, all at the same time using the waterfall display, or you can narrow the viewing spectrum down to any one particular band or portion of that bandwidth. For example, you could set up the software to monitor only the CW portion of the 14-MHz ham band and check for all the traffic that's found there. Or you can monitor those portions of the HF spectrum where shortwave broadcasters, utility, military, clandestine, or pirate stations are to be found.

Here's where the SDR-14 really becomes interesting: The software has the ability to make sample recordings of segments of RF to the hard drive in real time at a rate of 52 GB/day for a 150-kHz wide segment. The file created from that sampling contains *everything that has happened in that segment of frequencies for the duration of the recording.* The recording can be played back at any time through the SpectraVue software, and you can tune within that 150-kHz wide segment. It's just like actually tuning off the air! While tuning, you can also choose the appropriate demodulation modes or filters so you can analyze the recording for hidden signals and carriers you may have missed the first time you listened.

Again, say you wanted to record everything taking place within the CW portion of the 14-MHz ham band. You could capture a 24-hour period of events within that entire 150 kHz and be able to listen to every single transmission that was picked up by your antenna during that period in whichever order you wanted to. This is not like making an audio recording of one single frequency, hoping to be able to capture a signal that might appear there; instead you have a complete record of *all* the events that took place within that 150-kHz bandwidth and time period. Imagine the possibilities.

There many other important features of the SDR-14 of particular interest to serious radio monitors. For instance, there is built-in RF amplification of signals directly off the antenna, as well as the attenuation of strong signals, all of which is software controllable. You can also remotely control and listen to the SDR-14 across a high-speed network. You can directly monitor frequencies up to 200 MHz via an unfiltered/amplified antenna input, which can be used for listening to commercial FM, utility, and amateur radio stations. If you can build your own RF front-end converter, you can also use the SDR-14 for monitoring in the UHF/SHF regions.

You can also take the SDR-14 out for a virtual test run by downloading the SpectraVue software free from RFSpace's website along with the demo wav files that are available. The demo files have the 150-kHz recordings that will allow you to fully test the DSP and tuning features that are available using real-time signals.

The SDR-14 with its software cost $999 and is available directly from RFSpace or from Universal Radio, Inc. (www.universal-radio.com/catalog/commrxvr/0014.html).

Given the historic importance of both the SDR-1000/ROE and the SDR-14, I'm going to take a closer look at them in next month's column. I can't overstate how significant a breakthrough these products represent in radio monitoring methodology, one that will lead to radical change in the hobby. More importantly, the control codes for each of these SDRs are publicly available, so hobbyists can develop custom software applications to operate them. This in itself opens many opportunities for the hobby to revitalize itself by encouraging a greater degree of experimentation and the learning of new skill sets, like computer programming.

So ask yourself the question: Do I want to continue being an appliance operator who is dependent on the engineering skills of the radio manufacturer I purchase from, or do I want to create a radio that reflects my own monitoring needs by using my personal skills?

Next Month

In addition to our more detailed look at the SDR-1000/ROE and the SDR-14, we'll meet the people who developed these products. I may also take a second look at the USRP produced by Ettus Research for the GNU SDR software.

This is all leading up to a series of columns on how you can write your *own* software to use the features in each of these products with custom user interfaces you design yourself.

If you want to send me any questions, use my e-mail address carm_popcomm@hotmail.com. I cannot answer general questions on computers, but will be more than happy to help you with any issues raised in the columns. I'm also interested in any pictures you may have of your own computer-assisted monitoring station or stories about how you have built and run it.

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Please remember our troops overseas and give them your support. Visit the U.S. Department of Defense's official webpage, "Defend America." There (URL http://www.defendamerica.mil/support_troops.html) they provide an amazingly wide range of practical and useful ways you can directly help. Take some time to check out these resources and put them to use.

See you again next month!

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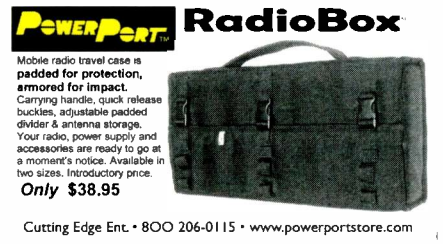
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by Joe Cooper, carm_popcomm@hotmail.com

Software-Defined Radio—Part VI: Getting Involved With SDR, What's Next?

Over the past five columns I've provided a detailed overview of a new technology called Software-Defined Radio, or SDR, that will completely change the way radios are built and used during the 21st Century. While the primary users of this new technology are to be found among military and commercial operators, a small number of SDRs are now available that are either in kit form or fully assembled. Last month I introduced you to three of those products: the Universal Software Radio Peripheral (USRP) by Ettus Research, the SDR-1000/ROE by Flex Radio, and the SDR-14 by RFSpace.

Building on this background, this month I'm going to take a closer look at the ways in which you can use each of these SDR products as a platform for creating your own custom digital signal processing (DSP) software control and detection programs. (If you need a refresher, go back and review the material already presented in the previous issues of *Pop'Comm*.)

A Virtual Homebrew

One benefit of this new radio technology is that it offers some real opportunities to get back into creating your own custom radio monitoring station. I'm sure that most of you have noticed the virtual disappearance of "hands-on" projects in radio hobby magazines over the past 10 years. This is due to the great changes that have taken place in electronic hardware through the expanded use of integrated circuitry and printed circuit boards. These developments, while making conventional electronic equipment smaller, more "feature-rich" and dependable, have also made hands-on construction of radio projects exceptionally difficult. However, thanks to computer programming, the creation of "virtual" circuitry can be surprisingly easy, even for the average computer user.

Certainly there is always going to be a learning curve whenever a new technology is encountered, but just as people mastered the coils, capacitors, and vacuum tubes of the 1920s, those who take the time can master the programming techniques that exist behind programming terms such as "DLL," "Event Procedures," "Methods," and "OCX." In doing so, they will become the new radio pioneers of the 21st Century.

Software Programming For SDR

Let's assume for a moment that you already know how to build software using popular programming languages such as MicroSoft VisualBasic or some flavor of C+. Now, how do you set out to learn how to create a program for one of the three SDR platforms that I've mentioned?

Well, frankly, you need three things to be successful in any type of software programming project: communication, programming information, and inspiration. Let me just briefly explain what I mean by each of these points.

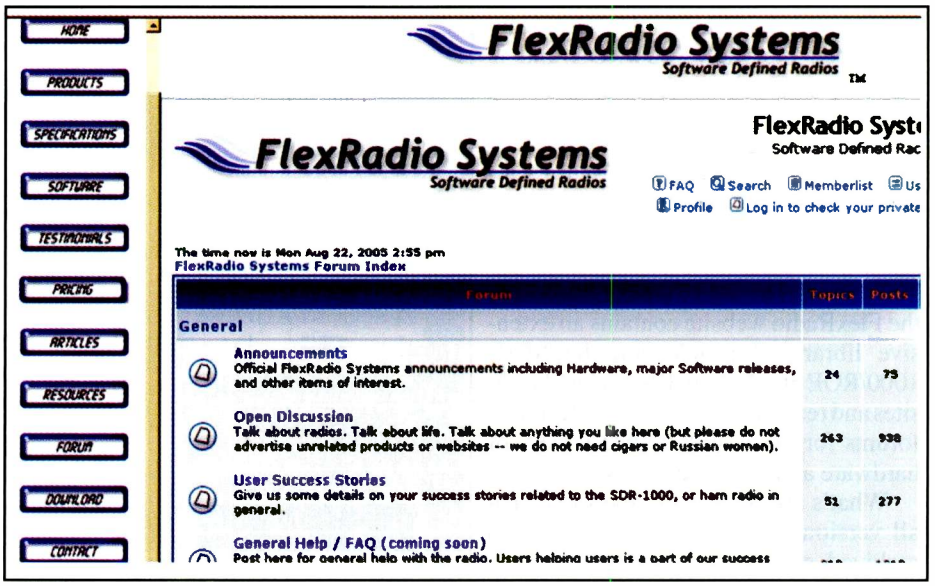
First, by communication I mean having direct access to the stakeholders who are working toward a similar software-programming goal. You will generally find this through published articles, books, and online discussion groups. By programming information, I mean the protocols you need to actually write the computer software that will tell a computer how to connect to and control an SDR. Since a protocol is a set of rules or standards that governs the way in which a computer communicates with an SDR, only the manufacturer of the SDR can provide this information. Finally, without inspiration there is simply no motivation for an individual to invest the necessary time and energy needed to make a software program work properly. Inspiration will come from those who have the imagination to look at SDR technology and see "the big picture" of how it will change the way that we use radios in the future.

Not surprisingly, when you take a look at the three SDR products I've described so far, you'll find these three elements were the basis of their development. Now let's take a look at each product from a software programmer's point of view, outlining where you can get communication, programming information, and inspiration for each of them.

USRP

As I outlined in last month's column, the USRP costs a reasonable $450 and contains the necessary analog-to-digital

FlexRadio Systems' website (www.flex-radio.com) offers the computer programmer a great deal of support for writing custom software for the SDR-1000 or to assist in the upgrade of the PowerSDR software supplied with the SD radio. This is thanks to the company's full support of an open source (GNU public license) software policy.



(A/D) converters needed to build an SD radio. You will also need to purchase up to four daughterboard RF front-ends, for $50 each, that will enable you to tune, or transmit, from 50 MHz to 800 MHz (others daughterboards are now being developed for other frequency ranges). The boards are available through online purchase from Ettus Research of Mountain View, California (www.ettus.com/).

One of the virtues of SDR technology is that the hardware component is of very simple construction, and the USRP is a very good example of that. All you need to do is unpack it, plug in the daughterboards, plug the power supply into an AC wall socket, plug the unit into a LINUX-based PC, and then download the firmware into the unit. You need only to keep an eye on an indicator LED on the USRP that flashes when the unit's CPU is processing information properly, and is "off" when it's not.

Things do get a bit tricky, though, in the actual installation of the software into your computer, which is not at all like the "plug-and-play" environment of Microsoft Windows. Rather than simply running an installation wizard that does most of the work, you must "build" the software, starting with a proper installation of LINUX itself. This where the communication, programming information, and inspiration formula comes into play. Fortunately all of the stakeholders involved with USRP technology, from the manufacturers to the end users, have set up a very good support network.

Thank GNU

The starting point—and really the heart and soul of amateur SDR technology—is the GNU (pronounced ghu-noo) Radio project, which was founded by Eric Blossom and Matt Ettus in 1998 (see www.gnu.org/software/gnuradio/). The purpose of the project is very straightforward: to ensure that everyone has free access to SDR technology that government interference in the free distribution of SDR software is legally challenged.

The GNU Radio project has its roots in earlier efforts by software programmers to prevent big corporations such as IBM and Microsoft, to name only two, from having near complete control over computer technology through the restrictive application of copyright laws to software programming. The two primary organizations that have worked to realize this idea are the Free Software Foundation (www.fsf.org/), and its public arm, the GNU project (www.gnu.org).

The GNU principle of open source, freely distributed software has gained great acceptance in the amateur radio community. For instance, as we'll see later Flex Radio Systems, maker of the SDR-1000, freely distributes its software and source-code using the GNU General Public license system developed by the Free Software Foundation.

So, basically you need to go to the GNU Software Radio URL at www.gnu.org/software/gnuradio/ and follow the instructions found there. All the software, documentation, and links to other sites that are connected to the project are found there as well. One of the best sites for support has been set up by Michael Gram, KD7LMO, who provides an excellent overview of the software installation process from the ground up (www.kd7lmo.net/ground_gnuradio_install.html).

Michael's website can also help you find that all-important component of inspiration. There you'll find described his application of the USRP and GNU SDR software as part of a high-altitude balloon project, where amateur radio VHF/UHF repeaters and ATV cameras are taken up to altitudes of 100,000 feet or more (you should see the video pictures that he gets at 18 miles up!). Truly, it's inspiration at its best!

Additional user-supplied support is offered through GNU Radio Wiki (comsec.com/wiki?GnuRadioWiki), which provides FAQs, step-by-step how-to articles, public forums, and reading lists. If you take your time and read through all of the material and ask questions, your chances of success will improve.

FlexRadio SDR-1000/ROE

If you want to develop software for SDR technology using Microsoft Windows as your operating system platform, your best bet is the SDR-1000/ROE, offered by FlexRadio Systems of Austin Texas (www.flex-radio.com).

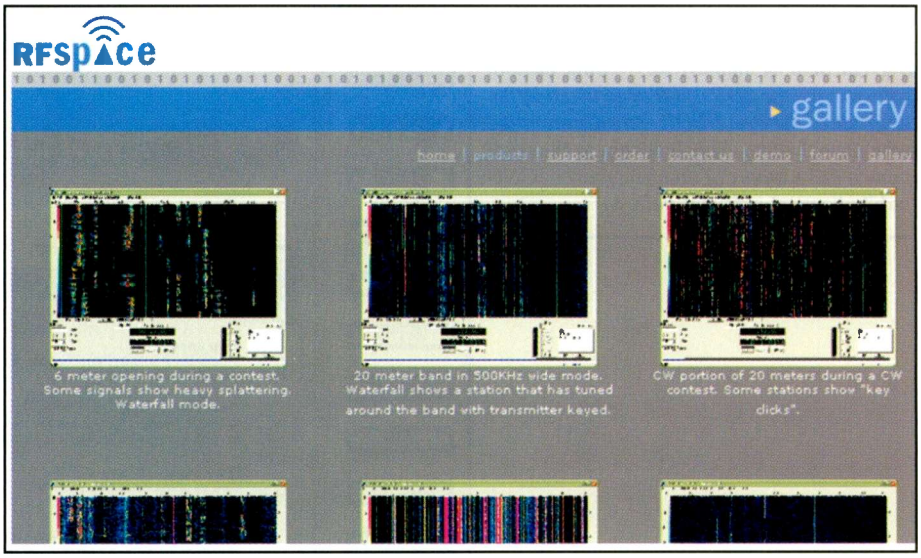
The entire software component of this product (called PowerSDR), including the source code, is available for free from the company's website under a GNU General Public License. This website contains a wealth of information on all things relating to SDR technology as well as to developing application software for the product.

Gerald Youngblood, AC5OG, who developed the SDR-1000/ROE and is president of FlexRadio Systems, actively encourages open source software development for his product. This means that anyone who follows the criteria for submitting revised code can see their improvements, or even new features, released as a new version of the software. To facilitate this open source approach, the FlexRadio website contains an extensive library of articles on the SDR-1000/ROE plus links to DSP-related websites and resources. It also offers 22 online forums for discussing a wide variety of hardware and software issues.

What's also nice about the site is that all versions of the software have been archived so you can go back and see exactly how the software has evolved, how problems were overcome, and how new features were installed. You can also download release notes, documentation, and WAV files that you can use to test the software without actually owning the hardware component. So even if you don't own the SDR-1000/ROE, you can still experiment with the software component and use it as a starting point for learning programming.

Interestingly, this particular SDR is programmed using Microsoft Visual Studio.Net. That software programming tool is going to be the starting point for the next series of columns that I'll be doing with the goal of showing you how to either create a custom user interface or to modify an existing software program, such as PowerSDR.

The key point is that if you just want to see what it is that software programmers do, you can take a tour through the FlexRadio website. Then, if you're serious about trying software programming (or improving upon existing skills), start going through the resources presented at that site in detail.


RFSpace
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6 meter opening during a contest. Some signals show heavy splattering. Waterfall mode.
20 meter band in 500KHz wide mode. Waterfall shows a station that has tuned around the band with transmitter keyed.
CW portion of 20 meters during a CW contest. Some stations show "key clicks".

The RFSpace website (www.rfspace.com) primarily outlines the product features of the SDR-14 in its primary function as an FFT spectrum analyzer. You can use this site to download the documentation required for writing your own custom software package so you can use the SDR-14's radio monitoring features to their fullest extent possible.

SDR-14

The SDR-14 from RFSpace (www.rfspace.com) is more than a simple communications receiver. It can be best described as being a FFT (Fast Fourier Transform)-based spectrum analyzer and digital receiver, where FFT refers to a procedure for calculating discrete frequency components from sampled time data.

Still, the SDR-14 is as true an SDR as it is a "black box" that sits outside your personal computer, and is primarily a high-speed analog-to-digital (A/D) converter. This means that it converts a broad spectrum (0 to 30 MHz) of RF signals into digital data and then processes that digital signal into the required *I* and *Q* format using a direct digital (D/D) converter.

The *I* and *Q* digital data created within the SDR-14 are sent to your personal computer via a USB 1.1 connection. All the spectrum display and detection functions are then performed on the personal computer using a Microsoft Windows-based DSP software package that comes with the SDR-14, called SpectraVue.

Unlike FlexRadio Systems, RFSpace has taken a more conventional approach, as the SpectraVue software package is usable in applications other than as the control and demodulation software for the SDR-14. Because SpectraVue is not provided as an open source software product the source code, as well, is not made available for change or modificatin as it is with the Power SDR software supplied with the SDR-1000.

However, having said that, the independent development of third party software for the SDR-14 is encouraged by RFSpace and the information required to do that is made freely available on a different website (see http://www.moetronix.com/files/sdr14interfacespec003.pdf). This documentation provides you with a detailed overview of how the SDR-14 transfers information back and forth between the "black box" and the computer using the USB port. With this information someone proficient in computer software programming can plug in the appropriate values into their code and create a custom software program.

Again, even if you do not want to try computer programming, it's well worth your while checking out RFSpace's and Moetronic's websites. You can download the SpectraVue program along with a number of WAV files. You can run those WAV files through the SpectraVue program to see how various modes of communication are managed, just as if you had the SDR-14 hooked up to your computer. Current examples provided in those files include satellite captures and a ham radio Earth/Moon/Earth (EME) echo, the 40-meter CW band during field day operations, and DRM (Digital Radio Mondiale) from CBC shortwave.

In addition to the downloadable documentation and software, there is also an online discussion group on the RFSpace webpage that focuses on programming issues. There is also a Yahoo group dedicated to the SDR-14 that has approximately 65 members, allows you access to Moe Wheatley, AE4JY (the designer of the "black box"), as well as a number of people who are active in developing their own software for the product.

Over the next series of columns we'll take a closer look at the interface specs to show you how to plug that information into a custom computer software program that meets your personal requirements.

Next Time

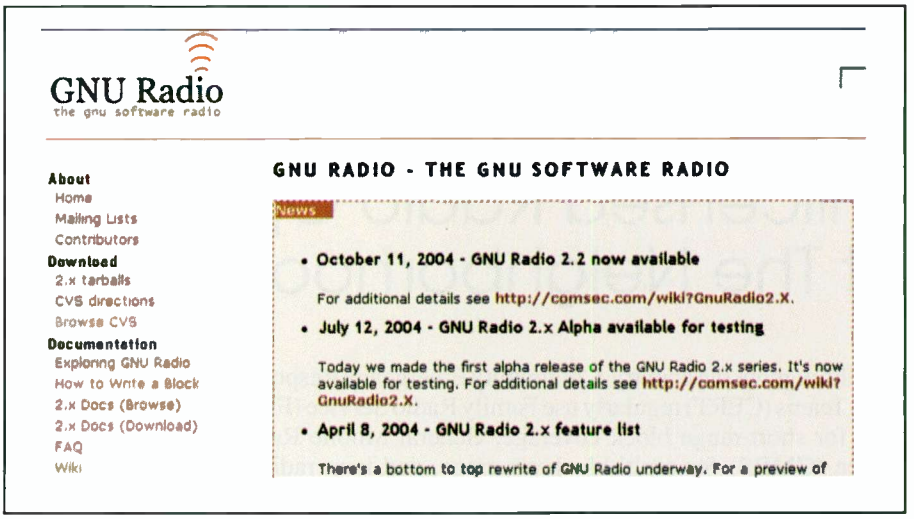
So now that I've given you an overview on exactly what SDR is and how its hardware and software components work, the next task will be to begin learn-

ing how to write computer software. To help you do this, I'm also going to show you how to get free legal versions of software for programming in C+ and Visual Basic from our good friend Bill Gates.

Remember that there is a bit of a learning curve involved in becoming proficient in software programming. I'm not going to be able to teach you *everything* you will need to know. All I can do is point you in the right direction, and then you're going to have to invest a little time and effort to make it all work.

Don't forget that you can e-mail me with any questions or pictures you may have of your own computer-assisted monitoring station or stories about how you've built and run it at carm_popcomm@hotmail.com. As mentioned before, I cannot answer general questions on computers, but will be more than happy to help you with any issues raised in the columns.

I have also placed a list of the columns I've done over the past two years, along with a summary of the content online. Please note that my personal webpage has moved to a new URL at www3.sympatico.ca/joe_in_ey. On that website, I've also included instructions on how to purchase back issues of *Popular Communications*.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• October 11, 2004 - GNU Radio 2.2 now available
For additional details see http://comsec.com/wiki?GnuRadio2.X.
• July 12, 2004 - GNU Radio 2.x Alpha available for testing
Today we made the first alpha release of the GNU Radio 2.x series. It's now available for testing. For additional details see http://comsec.com/wiki?GnuRadio2.X.
• April 8, 2004 - GNU Radio 2.x feature list
There's a bottom to top rewrite of GNU Radio underway. For a preview of

The GNU radio project homepage (www.gnu.org/software/gnuradio/) may not seem to have a great deal of information, but looks can be deceiving. Once you start exploring the site by clicking on its links, you're directed to a wealth of software resources and documentation that can help you build an SDR UHF/VHF receiver and transmitter (50 to 800 MHz), as well as a high-definition television receiver that you can operate through a LINIX-based computer.

Please also remember our troops overseas and give them your support. As I mentioned, the "Any Service Person" mail program has been suspended for security reasons, so instead refer to the U.S. Department of Defense's official webpage, "Defend America." They have a section found at /www.defendamerica.mil/support_troops.html with an amazingly wide range of practical and useful ways you can directly help.

See you again next month! ■

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